Copeland Creek Draft Restoration Plan for
Sonoma County, City of Rohnert Park
Country Club Drive to Snyder Lane
Sonoma County Water Agency

Revegetation will consist of planting California native species in suitable locations in the channel, along the side banks, and at the top of bank. The intent will be to establish vegetation that mimics natural communities typically found in the region occurring under similar environmental conditions. Additionally, disturbed soils will be hydroseeded with native grasses (and covered with erosion control fabric as specified in the design specifications) to discourage erosion and encourage a native herbaceous understory. Hydroseeding will be done prior to placement of erosion control fabric. Specific locations for each planting will be determined on site by a qualified biologist following sediment removal and thalweg (summer low flow channel) development. Specifics regarding each of these zones are described further below.

Planting Approach and Calculations

The number and density of tree and shrub species will be established following field visits. Plant densities are calculated by zone and based on area in square feet. To account for the additional area available on Channel Side Bank slopes, planting densities are based on the area calculated for a flat surface plus 11 percent. As part of a long-term plan to transition from non-native tree canopy to native tree canopy, the Agency is anticipating that selective removal of non-natives and encouraging native species will be sufficient to accomplish this goal over time. However, native herbaceous components of the riparian understory are generally lacking along this segment. Because of this, restoration of Copeland Creek following sediment removal will be limited to planting herbaceous understory species (mostly grasses and sedges) as well as establishing a more native assemblage of species that occupy the in channel habitat disturbed by the project.

Given that the substrate along this section of Copeland Creek is gravelly to sandy, in channel emergent plantings will include torrent sedge (*Carex nudata*) adjacent to the thalweg. In lieu of planting many shrubs on the channel sides which complicates the hydraulic capacity, Santa Barbara sedge (*Carex barbarae*) will be planted at 10-foot intervals along the toe (on both sides) to provide natural cover and improve stability. Native emergent species will be planted in the channel bottom to help stabilize the thalweg. Emergent plantings will be limited to portions of the channel bottom that are not permanently under water following sediment removal or up to 20 percent of the channel bottom area. However, all exposed disturbed areas will be hydroseeded.

Additional effort will be made during construction to retain or transplant (using oversized cuttings where feasible) some of the existing willows currently growing in the channel bottom. This may be accomplished during project construction or cuttings will be stored appropriately and planted during the restoration work. Trees established through transplanting and oversize cuttings are above and beyond the plant numbers enumerated in this plan and will augment planting densities.

Planting Zones

Three planning zones are identified for the project. These zones are Overbank, Channel Side Bank and In-Channel areas. These three distinct zones are based on topographic elevations relating to differing inundation durations by stream flow and/or period during which the soils are saturated. The Overbank

Zone is intended to develop into floodplain riparian forest eventually with 100 percent canopy cover. Plantable area for the Overbank Zone is calculated by subtracting access roads and v-ditches. The Channel Side Bank zone is also intended to develop into riparian forest and will be planted with riparian natives adapted to periodically saturated soils. These zones will be planted with herbaceous understory species typical of upper and lower the flood plain, such as, wild blue ryegrass (*Leymus triticoides*), red fescue (*Festuca rubra*), and meadow barley (*Hordeum brachyantherum*). As well as hydroseedieng exposed soils, these species will be plugged (in appropriate groupings) on 5-10 foot centers over approximately 10 percent of the overbank and side bank areas.

The In-Channel Zone is intended to reflect habitat characteristic of emergent freshwater wetland. The In-Channel zone remains wet throughout the year as a result of urban runnoff and will be planted with wetland species amenable to the hydraulic management needs of a flood control channel (e.g. small in stature, perennial, rhizomatous, and can survive being submerged for long periods). These species will be plugged (in appropriate groupings) on 5-10 foot centers in 20 percent of the area above the thalweg.

Plant Material

The plan focuses on using native plant species in densities and compositions that approximate natural plant communities found regionally in riparian areas and blend with nearby natural plant communities. Plant material will be obtained from local sources preferentially as feasible. Table1 displays the list of the species planned to be established following sediment removal on Copeland Creek. Herbaceous species will be planted from liners. Overbank and Channel Side Bank zones will also be seeded with native species with the composition and application rates specified in Table 2. The seed mixture will either be collected locally onsite or will be obtained from a seed supplier that can authenticate a regionally local source and augmented with additional native perennial grass seed collected locally.

Table 1. Draft Plant Species For Planting In-Channel, Channel Side Bank and Overbank Riparian Zones

Overbank and Channel Side Bank Zones				
	Scientific Name	Common Name	Estimated Quantity	Size
	Carex barbarae	Santa Barbara sedge	400	Liner
	Leymus triticoides	wild blue ryegrass	200	Liner
	Hordeum brachyantherum	meadow barley	200	Liner
	Festuca rubra	red fescue	200	Liner
In-Channel Zone		Total Area= 0.58 acres or 25,265 square feet=20%=5,053 square feet= or >202 plants		
	Carex nudata	torrent sedge	400	Liner
	Eleocharis macrostachya	pale spikerush	100	Liner
	Juncus balticus	baltic rush	100	Liner
	Juncus phaeocephalus	brown-headed rush	100	Liner

Table2. Draft Seedmix and Application Rates

Scientific Name	**Common Name**	**Application Rate (lbs/acre)**
Leymus triticoides	beardless ryegrass	20
Hordeum brachyantherum	meadow barley	20
Festuca rubra	red fescue	10
Lupinus bicolor	bicolor lupine	5
Vulpia microstachys	Nuttall's fescue	5
Total lbs/acre		**60**

Implementation

Planting will be conducted and supervised by a qualified biologist. Precise location of trees and shrub plantings in the upland and riparian zones will be determined in the field following completion of the sediment removal. Planting will be conducted in late summer and early fall.

Irrigation

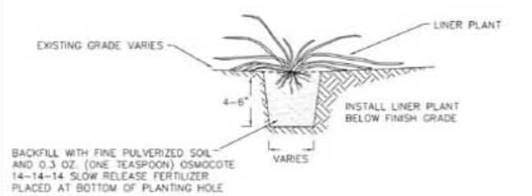
No irrigation is anticipated to be required to establish the herbaceous species proposed. In-Channel plantings will be irrigated through the summer from urban run-off in the channel. Channel Side Bank and Overbank zones will be planted coinciding with the advent of the rainy season. A single season should be adequate to allow the plant plugs to get established as herbaceous species have a natural tendency to go dormant through the dry season.

Planting

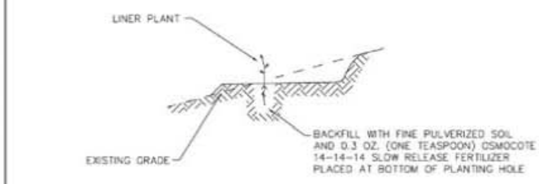
Agency personnel will conduct plant installation.

Monitoring

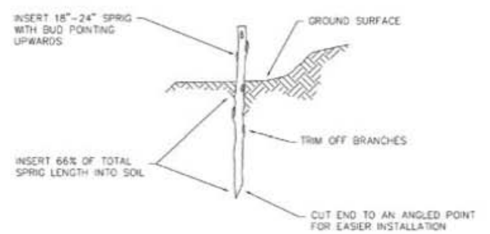
Monitoring will be conducted at the project site for three (3) years following construction and planting. Site conditions will be documented annually by taking photographs at permanent photo points. Monitoring will be conducted to evaluate the efficacy of the revegetation methods and to develop corrective measures, if required. Monitoring will involve collecting quantitative data on cover by dominant herbaceous species, cover by shrub and tree species, as well as percent survival for planted trees and shrubs.



GRASS LINER INSTALLATION DETAIL
NOT TO SCALE



NO HARDWARE INSTALLATION DETAIL
NOT TO SCALE



DORMANT WILLOW OR COTTONWOOD SPRIG INSTALLATION
NOT TO SCALE

Right: Example revegetation plan. Species and composition may change due to plant availability or planting conditions.

EXAMPLE Revegetation Plan

Scientific Name	Common Name	Flag Color	Number of Plant Locations							Container Size	Spacing (F.O.C.)
			Reach 1		Reach 2		Reach 3				
			1,336'	1,412'	789'	768'	1,276'	1,295'	6876'		
			Zone A	Zone B	Zone C	Zone D	Zone E	Zone F	TOTAL		
SHRUBS											
Baccharis pilularis	Coyote Bush		25	25	25	25	35	35	**170**	supercell	4-6'
Calycanthus occidentalis	Spice Bush		5	5	0	0	10	10	**30**	supercell	4-6'
Heteromeles arbutifolia	Toyon		50	50	10	10	30	30	**180**	treeband	4-6'
Rhamnus californica	Coffeeberry		20	20	10	10	20	20	**100**	treeband	4-6'
Rosa californica	California Rosa		50	50	25	25	50	50	**250**	treeband	4-6'
Sambucus mexicana	Blue Elderberry		0	0	10	10	0	0	**20**	dee pot	4-6'
Symphoricarpus albus	Snowberry		20	20	0	0	0	0	**40**	treeband	4-6'
TREES											
Acer macrophyllum	Big-Leaf Maple		10	5	0	0	0	0	**15**	supercell	10-12'
Acer negundo	Box Elder		0	0	5	0	0	10	**15**	supercell	10-12'
Aesculus californica	California buckeye		0	0	5	0	5	5	**15**	tree pot	10-12'
Fraxinus latifolia	Oregon Ash		0	0	0	0	5	0	**5**	supercell	10-12'
Juglans hindsii	N. California Black Walnut		0	10	0	0	0	5	**15**	dee pot	10-12'
Populus fremontii	Fremont's Cottonwood		0	0	0	5	0	0	**5**	dee pot	10-12'
Quercus agrifolia	Coast Live Oak		10	5	0	0	0	5	**20**	supercell	10-12'
Quercus lobata	Valley Oak		5	5	0	10	10	0	**30**	deepot	10-12'
Umbellularia californica	California Bay		0	0	5	0	5	0	**10**	deepot	10-12'
DORMANT CUTTINGS											
Salix sp.	Willow		25	25	15	15	20	20	**120**	cutting	2-4'
EMERGENTS											
Juncus spp.	Rush		200	200	200	200	200	200	**1200**	supercell	1-3'
Carex spp.	Sedge		200	200	200	200	200	200	**1200**	supercell	1-3'
Leymus triticoides	Creeping wild-rye		300	300	300	300	300	300	**1800**	supercell	1-3'
Elymus glaucus	Blue wild-rye		300	300	300	300	300	300	**1800**	supercell	1-3'
Festuca sp.	Festuca		300	300	300	300	300	300	**1800**	supercell	1-3'
TOTAL:			**1520**	**1520**	**1410**	**1410**	**1490**	**1490**	**8840**		

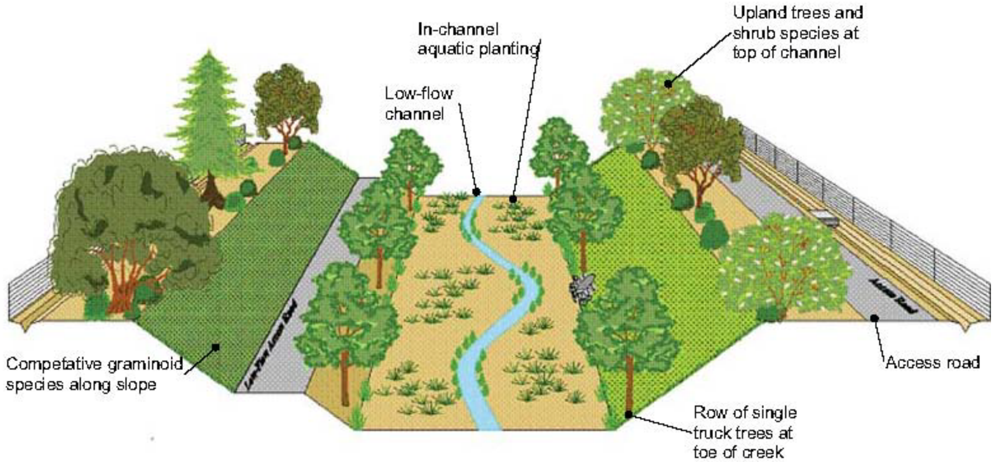


FIGURE 1. SCWA Stream Mantenance Program Goals:

Creek channels managed by SCWA are planted with a row of inundation tolerant single trunked trees along the toe of the creek. Single trunk trees include; red willow, pacific willow, cottonwoods, Oregon ash and big leaf maple. In-between the single trunk trees SCWA plants sedges, rushes and various grass species and occasionaly shrub species such as dogwood, elderberry, and spicebush. The lower 2/3 of the creek channel will be planted with and dominated by graminoids that are highly competative against the non-native annuals. Graminoid species include creeping wild-rye, blue wild-rye, and various fescue species. The upper 1/3 and top of the creek channel is planted with a single row of upland trees; oaks, bay, buckeye and box elder. Disbursed throught the upland tree plantings are the understory shrub species; toyon, coffeeberry, twinberry, snowberry, rose and coyote bush.

SONOMA COUNTY WATER AGENCY

Stream Maintenance Program

Draft Manual

Prepared for:

Sonoma County Water Agency
404 Aviation Boulevard
Santa Rosa, CA 95406
Contact: Jon Niehaus
707/547-1947

Prepared by:

Horizon Water and Environment
1330 Broadway, Suite 424
Oakland, CA 94612
Contact: Ken Schwarz
510/986-1851

With contributions from:

Alnus Ecological
Contact: Jim Robins
510/482-5430

January 2009

Horizon Water and Environment. 2009. *Stream Maintenance Program Manual*. Draft. January. (HWE 08.002.) Oakland, CA.

TABLE OF CONTENTS

List of Appendices

List of Tables

After page:

List of Figures

All figures located at end of chapter

LIST OF ACRONYMS

ARM	Agreement for Routine Maintenance
BA	Biological Assessment
BAAQMD	Bay Area Air Quality Management District
Basin Plans	water quality control plans
BMP	Best Management Practices
BO	Biological Opinion
°C	Celsius
CCC	Cotati Creek Critters
CDFG	California Department of Fish and Game
CEQA	California Environmental Quality Act
CESA	California Endangered Species Act
cfs	cubic feet per second
CFWS	California freshwater shrimp
City	City of Santa Rosa
CIP	capital improvement projects
CMP	corrugated metal pipe
CNDDB	California Natural Diversity Database
CNPS	California Native Plant Society
CSC or SSC	California Species of Special Concern lists
CSCB	Coho Salmon Captive Broodstock
CSWP	Central Sonoma Watershed Project
CVFF	Coyote Valley Fish Facility
CWA	Clean Water Act
cu. yds.	cubic yards
DCFH	Don Clausen Fish Hatchery
DPR	California Department of Pesticide Regulation
DSOD	California Division of Safety of Dams
EA	Environmental Assessment
EFH	Essential Fish Habitat
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
ESA	Endangered Species Act
F&G Code	California Fish and Game Code
FCDC	Flood Control Design Criteria
FE	Federally Endangered
FEMA	Federal Emergency Management Agency
FIRM	flood insurance rate map
FLD	Flood Peak Attenuation/Flood Water Storage
FMP	Fishery management plans
ft.	feet
GIS	geographic information system
IAWG	Inter Agency Working Group
IP	Individual Permit
IS	Initial Study
K(f)	Soil Erodibility Factor
LID	Low Impact Development
LWD	large woody debris

m	meters
MBTA	Migratory Bird Treaty Act
MCRRFCD	Mendocino County Russian River Flood Control and Water Conservation Improvement District
MEP	Maximum Extent Practicable
MOA	Memorandum of Agreement
MS4	municipal separate storm sewer system
MSL	mean sea level
NEPA	National Environmental Policy Act
NFIP	National Flood Insurance Program
NHPA	National Historic Preservation Act
NMFS	National Marine Fisheries Service
NOI	Notice of Intent
NCRWQCB	North Coast Regional Water Quality Control Board
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
NWPs	nationwide permits
OHWM	Ordinary High Water Mark
PRMD	Permit and Resource Management Department
RCDs	Resource Conservation Districts
RWQCBs or Regional Boards	Regional Water Quality Control Boards
RGL	Regulatory Guidance Letter
RGP	Regional general permits
RPACCC	Rohnert Park and Cotati Creeks Council
RPM	Reasonable and Prudent Measures
RUSLE	Revised Universal Soil Loss Equation
SAA	Streambed Alteration Agreement
SFBRWQCB	San Francisco Bay Regional Water Quality Control Board
SCWA or Agency	Sonoma County Water Agency
SHPO	State Historic Preservation Officer
SMP	Stream Maintenance Program
sq. mi.	square miles
SRPCS	Santa Rosa Plain Conservation Strategy
SSURGO	Soil Survey Geographic Database
Stream Policy	Stream and Wetlands System Protection Policy
SUSMP	Standard Urban Storm Water Mitigation Plan
SWMP	Storm Water Management Plan
SWPPP	Storm Water Pollution Prevention Plan
SWRCB or State Board	State Water Resources Control Board
TMDL	Total Maximum Daily Load
TOB	top-of-bank
USACE	United States Army Corps of Engineers
USCFF	United States Commission of Fish and Fisheries
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WDR	Waste Discharge Requirements
WPP	Watershed Partnerships Program

Chapter 1
INTRODUCTION AND PROGRAM SUMMARY

1.1 Program Background and Need

The Sonoma County Water Agency (SCWA or Agency) was created as a special district in 1949 by the California Legislature to provide flood protection and water supply services to portions of Sonoma and Marin counties. Legislation enacted in 1995 added the treatment and disposal of wastewater to SCWA's responsibilities. Today, SCWA is a multi-objective and integrated water resources agency providing many services that integrate natural resource management including providing water supply, flood protection services, treatment of wastewater and distribution of recycled water, and recreational opportunities. SCWA's mission and vision statements are as follows:

> SCWA Mission Statement:
>
> *The mission of Sonoma County Water Agency is to effectively manage the resources in our care for the benefit of people and the environment in our service area (Sonoma County Water Agency 2007a).*
>
> SCWA Vision Statement:
>
> *The Agency will achieve the sustainable use of natural resources in all aspects of water resources management (Sonoma County Water Agency 2007).*

The Stream Maintenance Program (SMP) was developed by SCWA to improve and define the management and maintenance of flood control channels and streams under SCWA's authority. The SMP establishes programmatic guidance to conduct maintenance activities and avoid and minimize environmental impacts. The SMP also provides the organizational framework to oversee routine channel maintenance activities and ensure the program is compliant with the terms and conditions of its permits. The SMP was developed to be consistent with SCWA's mission and vision statements.

As background to the SMP it is important to note that SCWA has operated and maintained engineered, modified, or natural channels for several decades. Many of the engineered channels included in this SMP Manual were initially constructed as a result of the Central Sonoma Watershed Project (CSWP) Work Plan (Sonoma County 1958) in the Laguna de Santa Rosa watershed. The 1958 CSWP Work Plan described facility and channel maintenance as follows:

> *The Flood Control District[1] will assume full responsibility for operating and maintaining all structural works of improvement installed under this plan in such a*

[1] Flood Control District was a predecessor agency to today's SCWA.

manner that they will serve the purpose for which they were installed, to the degree for which they were designed (Sonoma County 1958).

The original Work Plan did not provide detailed guidance on how routine maintenance should occur for the CSWP. However, the Work Plan did require that all works were to be inspected twice annually and after each major flood event. Spring, fall, and other interim inspections were to occur as needed to determine required maintenance activities prior to the coming rainy season. Since the CSWP program, several other channels and facilities have been constructed within the Laguna de Santa Rosa, Petaluma River and Sonoma Creek watersheds. Since the initial flood management programs of the 1950s, routine maintenance needs have been assessed and prioritized through seasonal and annual inspections with sediment removal, bank stabilization, and vegetation management activities prioritized as necessary following inspections. It is also worthwhile to note that the original channel design capacities for the CSWP and other programs typically assumed that the stream banks would be maintained in grass vegetation with little or no tree growth and that the streambed would be maintained clear of vegetation and sediment.

Over the years SCWA's stream management perspective has expanded to include multiple objectives including resource protection and environmental sustainability in addition to just flood control and channel maintenance. The Agency has also received requests from the public to incorporate more environmentally conscious management principles, such as wildlife habitat enhancement, into stream maintenance activities. Additionally, local, state, and federal regulations and their requirements have changed over time. Compliance with federal environmental laws and regulations such as the federal Endangered Species Act (ESA) and Clean Water Act (CWA), and state laws and regulations administered by the California Department of Fish and Game (CDFG) and Regional Water Quality Control Boards (Regional Boards or RWQCBs) has required an increasingly extensive authorization process.

Prior to the SMP, each individual maintenance project underwent separate permit approval. This typically involved submitting between 5-15 individual permit applications to various regulatory agencies per year. The time, effort, and costs of the annual permitting process were key factors in developing the SMP. The annual permitting process required a 10 to 18 month planning and application process for a work period that typically lasted only 3 to 4 months. Likewise, the costs of annual permitting often exceeded the costs of the maintenance work itself. Similarly, the work effort and time commitment for the regulatory agencies had also become heavy. As a result, for both SCWA and the regulatory agencies, the annual permitting process for routine and repeating maintenance activities had become inefficient. The RWQCBs specifically requested that SCWA develop a long-term plan to streamline and shorten this annual permitting process.

Beside the time and effort requirements for the annual permitting of maintenance projects, there was also a loss of maintenance efficiency and resource protection with planning projects individually. The SMP was developed to provide consistent program actions, avoid and minimize program impacts, characterize Program Area resources, develop suitable mitigation, and provide oversight across the Program Area. An integrated SMP will better utilize time and funding, and offer a regional perspective for resource management versus developing and permitting a series of individual projects year after year. It is with this background and need that the SMP was developed.

1.2 Program Purpose and Objectives

The primary purpose of the SMP is to provide an efficient and organized program to conduct stream maintenance activities, comply with all relevant environmental regulations, and maintain flood capacity while enhancing the Program Area's natural resources. The SMP has been developed carefully to balance these goals of flood protection, permitting, and protecting and enhancing natural resources.

The following list summarizes the SMP objectives:

- Provide adequate flood protection and channel conveyance capacity for channels under SCWA authority;
- Use a systemic and scientific understanding of the watershed and individual stream reaches to guide maintenance activities;
- Use the stream system understanding to develop informed maintenance approaches that avoid and minimize environmental impacts;
- Improve communication, coordination, and permitting efficiency between regulatory agencies and SCWA through an open and collaborative program notification and reporting process;
- Develop an adaptable and sustainable program that can respond to changing environmental, maintenance, and regulatory conditions;
- Provide an administratively stable program that provides consistency in oversight and implementation of program activities;
- Obtain long-term permits providing coverage of program activities under Federal and State regulations such as ESA and CWA; and
- Comply with the California Environmental Quality Act (CEQA) and National Environmental Protection Act (NEPA) requirements.

The purpose of this SMP Manual is to establish and define the overall maintenance program and describe the program's maintenance activities, natural resources, and approaches to avoid or minimize impacts to environmental resources. This SMP Manual is intended for use by SCWA maintenance staff, engineers, and resource managers, as well as environmental regulatory agency staff and other watershed stakeholders.

This SMP Manual provides a description of the activities that will be conducted as part of the SMP. As such, this manual serves as the description of activities permitted by the relevant regulatory agencies. The evaluation of program environmental impacts is addressed through a parallel Environmental Impact Report (EIR) developed in compliance with CEQA. The SMP EIR uses the description of program activities in this manual as the basis for its evaluation.

The SMP is envisioned to be a flexible program subject to periodic revisions reflecting improved understanding of resource conditions, maintenance technologies, or management practices over time. In developing the program and supporting the technical needs of this

SMP Manual, the SMP EIR, and the programmatic permits, several additional technical studies and coordinating activities were conducted, including:

- Inventorying and assessing the natural resources of the Program Area including vegetation mapping and identification of special status plant, wildlife, and fish species;
- Conducting a wetland delineation for the Program Area's engineered flood control channels;
- Evaluating geomorphic and biologic conditions for each engineered flood control channel in the Program Area;
- Evaluating the Program Area's cultural and historic resources;
- Creating an SMP data management system to organize program information and communicate information regarding maintenance activities and natural resources;
- Developing an operations manual for stream maintenance activities;
- Developing a sediment disposal plan for the SMP;
- Revising SCWA's current hydrology and flood control design criteria manual;
- Establishing an Inter-Agency Working Group (IAWG) comprised of regulatory agency representatives to provide the program guidance and regulatory coordination through an open and transparent forum; and
- Establishing an integrated watershed mitigation program to help mitigate environmental consequences of the SMP through stream restoration, erosion control, education and other land management practices implemented by local partner organizations.

1.3 Program Area and Channel Types

Figure 1-1 presents the SMP Program Area located in Sonoma County, California and shows SCWA's jurisdiction organized into nine flood control zones, Zones 1A – Zone 9A. The great majority of SMP activities (over 95%) are located in the engineered flood control channels of Zones 1A, 2A, and 3A – the Laguna de Santa Rosa, Petaluma River, and Sonoma Creek watershed, respectively.

Of these three primary zones of activity, most maintenance activities occur in Zone 1A (Figure 1-2). The majority of the flood control channels of the Program Area are found in the greater Santa Rosa and Rohnert Park regions. These channels of Zone 1A require the most maintenance attention, with typically several projects occurring annually. Maintenance activities in Zone 2A (Figure 1-3), the Petaluma area, are the next most common, with typically only one or two sediment and vegetation removal projects per year. Maintenance activities in Zone 3A (Figure 1-4), the Sonoma Creek watershed, are even less common. Maintenance activities in the other six zones are rare and are not expected to occur with any regular frequency.

There are four different channel types in the Program Area. The zone maps presented in Figures 1-2 through 1-9 include color designations for the four types of channel, and Figure 1-10 provides photograph examples of each type. A typical cross section of an engineered flood control channel is shown in Figure 1-11, illustrating many of the channel features (e.g., top-of-bank, toe-of-slope, etc.) that are referred to throughout this document.

The ownership and general maintenance activities for the four channel types are described below:

Engineered Channel–Owned in Fee (Red Channels): These channels are owned and maintained by SCWA through limited zone-specific property taxes. SCWA is responsible for maintenance of the flood control channels that it owns. SCWA maintains approximately 61 miles of owned in fee-engineered channels. Engineered channels are channels that were designed and built to convey a design discharge. In the Program Area, engineered channels have typically been built with a trapezoidal cross-sectional shape. Most of the engineered channels have earthen banks and streambeds, however some channels have hardened banks and beds. Bed and bank hardening typically occurs at or near road and culvert crossings to protect these structures. Maintenance activities in these engineered channels include bank stabilization, landscaping, fencing, mowing, sediment removal, debris removal, vegetation thinning, herbicide stump treatment, and access road herbicide spraying. Structures such as access roads, drop inlet culverts, outfalls, flap gates, and road crossing culverts constructed in association with the engineered channels also require routine maintenance. Owned in fee-engineered channels are shown in red in the zone maps of Figures 1-2 through 1-9.

Engineered Channel–Easement Maintained (Orange Channels): These channels are not owned by SCWA, but SCWA performs channel maintenance on them through permissive easement agreements. For example, cities such as Petaluma or Rohnert Park may own such channels and may have entered into easement agreements with SCWA to conduct maintenance. These easement agreements authorize SCWA to conduct maintenance, but do not require or obligate SCWA to maintain any specific level of hydraulic capacity or conduct any maintenance. Generally, the level of maintenance is defined by the municipality and implemented by SCWA. SCWA performs some maintenance activities within approximately 15 miles of easement engineered channels. Maintenance activities in these channels are similar to the activities described above for SCWA-owned engineered channels with the exception that for the easement engineered channels, SCWA works only within the channel banks and does not maintain roads, ditches, fences, or other structures outside the channel. Easement engineered channels are shown in orange in the zone maps of Figures 1-2 through 1-9.

Modified Channel–Easement Maintained (Blue Channels): Modified channels are natural channels with existing earthen beds and banks that have been modified either through vegetation removal, in-channel grading, channel widening or straightening, or debris clearing to improve flow conveyance. Though modified, these channels are not engineered or constructed according to specific design criteria to convey a discharge of a particular magnitude. These are permissive easements where another jurisdiction, authority, or private landowner owns the modified channel feature. SCWA is not obligated to conduct maintenance and has no responsibility to perform any specific level of maintenance in easement modified channels. However, SCWA may perform limited maintenance on these channels. SCWA holds hydraulic easements (for work within the channel) for over approximately 49 miles of modified channels. Maintenance activities in modified channels typically include the removal of log jams, debris jams, and clearing vegetation to remove significant flow obstructions. The most common type of work conducted in these channels is the removal of blackberry thickets or fallen trees that significantly increase the potential for flood damage to structures. Trash or vegetation debris may also cause a blockage and require removal. SCWA does not perform sediment removal or bank stabilization work in modified channels. Work in modified channels occurs only on an as-needed basis, usually at the request of an adjacent land-owner during or following a large storm event. Modified channels are shown as blue streams in the maps of Figures 1-2 through 1-9.

Natural Channel–Easement Maintained (Green Channels): Natural channels are non-engineered and non-modified creek systems with a permissive clearing easement. SCWA holds hydraulic easements to work within the channel banks for over approximately 80 miles of natural channels. Natural channels may require maintenance activities to maintain flow conveyance and reduce the flooding hazard. Maintenance work in natural channels typically involves clearing debris or vegetation that is causing a flow obstruction. In this way, maintenance activities for natural channels are similar to modified channels. Work in natural channels is infrequent and typically occurs at the request of an adjacent landowner who has observed a problem. Similar to modified channels, SCWA does not conduct sediment removal or bank stabilization activities in natural channels. Additional environmental protections are included for natural channels as described in Chapter 6, Section 6.5.2 *Natural Channels*. Natural channels are shown as green creeks in the zone maps of Figures 1-2 through 1-9.

1.4 Overview of SMP Approach

This SMP Manual was developed with past maintenance lessons in mind to create an improved program that would maintain channels more effectively, would provide greater environmental protection and benefits, and would be more time and cost efficient for both SCWA and regulatory agency staff. The development of the SMP benefited from review of other stream maintenance programs throughout the state and incorporation of their experiences.

The central tenet of the SMP approach is that management activities are conducted using an informed and systemic approach to minimize stream impacts while providing necessary flow conveyance. A thorough understanding of the physical and biological stream system is at the core of this informed approach. As described in subsequent chapters (Chapter 3 *Environmental Setting,* Chapter 4 *Channel Characterization*) the SMP utilizes an analytic and targeted approach to understand the degree of maintenance work actually required for a given situation. For example, hydraulic and field analysis can be used to assess and guide sediment removal activities whereby flood control channel cross sections can be compared to as-built designs to determine when sediment removal is necessary. In this way the removal of sediment will not be arbitrary or excessive.

While the analysis of maintenance problems may be focused, the development of solutions is watershed-wide in perspective. For example, in the sediment removal case described above, the SMP approach also considers how to reduce in-stream sediment loads from erosion "hot spots" in the watershed lands upstream that are introducing large amounts of sediment to the stream system downstream (see the integrated watershed mitigation program described in Chapter 8 *Program Mitigation*).

The SMP employs a more comprehensive watershed approach than the current project-by-project annual process. The watershed approach of the SMP manages streams and channels with an understanding of the overall stream system and its physical and biological processes. The SMP approach considers each site and reach as a component within a watershed system integrating upstream inputs and downstream outputs. Such a perspective enables improved management of resources across the whole watershed system. For example, consideration of sensitive habitats, sediment sources in the upper watershed areas, or the most efficient way to manage a stream corridor's vegetation are all improved in planning and implementing maintenance through a broader program.

1.5 Program Activities

The Stream Maintenance Program has three primary activities: sediment management, vegetation management, and bank stabilization. These core maintenance activities occur mainly in engineered flood control channels (red and orange channels on Figures 1-2 through 1-9), but may also occur in other engineered structures, sediment basins, or other facilities on an as-needed basis. In addition to the three core SMP activities, the SMP also involves other smaller and infrequent maintenance activities such as road maintenance, sediment removal around reservoir inlet structures, and debris removal. The SMP also includes the transport and disposal of collected sediment and vegetation. SMP activities are summarized below and described in more detail in Chapter 6 *Maintenance Activities*.

1.5.1 Sediment Management

In general, sediment management refers to the removal of excess accumulated sediment from engineered flood control channels and facilities. This accumulated sediment reduces flow capacity and increases the potential for flooding. SMP sediment management activities seek to provide flow capacity while also providing geomorphic and ecologic channel functions, through such means as shaping a two-stage channel form (see Chapter 6) within the original engineered flood control channel (Figure 1-11). Sediment management activities are generally conducted from June 15th to October 31st when streams are typically at their driest. The number of sediment removal projects undertaken annually and the quantity of sediment removed in a given year depend on recent weather and hydrologic conditions, as well as the frequency and extent of past maintenance activities.

There are three general types of sediment removal projects: (1) reach scale projects where sediment is removed from an entire reach (typically 1000-3,000 ft long); (2) smaller localized sediment removal projects (typically 100-200 ft long) where sediment is removed from individual crossings, culverts, or other in-channel facilities; and (3) intermediate scale sediment removal projects (typically 500-750 ft long) that involve individual bar grading or geomorphic shaping activities to remove sediment, reduce flow deflection, and enhance channel habitat features.

Sediment removed from SCWA facilities will be hauled off-site to suitable upland disposal sites or to the Sonoma County Central Landfill. Sediment disposal activities are essential to the completion of the sediment removal, bank stabilization, and vegetation removal activities of the Program. SCWA anticipates that on average, the SMP will involve removing between 10,000 and 25,000 cubic yards of sediment per year. More detail on sediment disposal activities is provided in the following chapters.

1.5.2 Vegetation Management

Vegetation management refers to the trimming, mowing, and removal of flow-constricting vegetation within the flood control channels and other constructed facilities. Vegetation management activities are conducted to maintain flow conveyance capacity, establish a canopy of riparian trees, and control invasive vegetation. Vegetation management and removal activities are relatively consistent from year to year, though locations change depending on recent growth and blockages. Vegetation management also includes the planting of new trees and shrubs in engineered channels in accordance with the SMP's restoration and mitigation program (see Chapter 8 *Program Mitigation*).

1.5.3 Bank Stabilization

The repair and stabilization of stream or reservoir banks is undertaken when a bank is weakened, unstable, or failing. Negative consequences of failing stream banks include:

- causing damage to adjacent properties;
- increasing the flood hazard and threaten public safety;
- impairing roads, transportation, and access;
- generating erosion and increasing downstream sediment yields; and
- impacting riparian habitat and other natural resources.

Bank stabilization activities may occur in engineered channels or other facilities including culvert outlets and banks around reservoirs. Bank stabilization activities are generally conducted June 15th to October 31st when streams are at their driest.

1.5.4 Other Activities

Other Program maintenance activities include:

- maintaining channel access roads for accessibility;
- maintaining proper drainage along channel access roads;

- maintaining proper functioning of drop-inlet culverts which direct local surface flow toward the flood control channels;
- maintaining culverts free of sediment and vegetative blockages;
- sediment removal around reservoir inlet structures
- repairing fences along the channels; and
- removing or covering graffiti on Agency facilities.

The majority of these activities are considered to be minor and small in scale.

1.5.5 Activities in Modified and Natural Channels

As described above, maintenance activities in modified and natural channels (blue and green channels as shown on Figures 1-2 through 1-9) occur on an as-needed basis usually following large storm events or particularly wet winters with seasonally elevated stormflows. Maintenance in these reaches is conducted only to maintain hydraulic conveyance and reduce flooding potential. For example, SCWA may remove a fallen tree or debris jam that backwaters flows upstream or diverts flows toward a bank or structure in a natural channel. Maintenance may also be required when overgrown vegetation blocks a culvert. Such flow blockages can lead to more excessive bank erosion, the undermining of a facility, or potential overbank flooding if not removed. Maintenance in these channels is usually conducted at the request of an adjacent landowner.

During the SMP development and review process, representatives from the National Marine Fisheries Service (NMFS), the U.S. Fish and Wildlife Service (USFWS), CDFG, and Regional Boards identified concerns about maintenance activities conducted in natural channels (where SCWA has hydraulic easements) that support listed salmonids and/or California freshwater shrimp. Through discussions with these agencies, SCWA agreed to remove these channels of concern from coverage under the SMP. As a result, potential direct impacts to these species and their habitat are avoided. The streams supporting sensitive habitats that were removed from the SMP are shown in Figure 1-12. These channels are also represented by green dashed lines in the maps of Figures 1-2 through 1-9.

The one creek that is known to support California freshwater shrimp but was not removed from the SMP is Sonoma Creek. This creek is mostly comprised of modified and natural channel reaches. Two short segments of SCWA owned-in-fee engineered channels are located on the main stem of Sonoma Creek. These reaches are relic parcels that came under SCWA ownership at some point in the past, but are managed by SCWA as if they were modified or natural channel and are treated by this SMP as a natural or modified channel (i.e., no sediment removal or bank stabilization activities will be covered in those reaches by this SMP). Because several homes border this creek, risks to property and safety due to flow blockages and potential flooding exist and SCWA may need to conduct vegetation management in Sonoma Creek. However, specific BMPs to conduct maintenance in this creek were developed to greatly reduce the potential for impacts to California freshwater shrimp (see Table 7-1).

1.5.6 Activities Not Covered in the SMP

Activities not covered under the SMP include:

- maintenance activities on the main stems of the Russian River and Dry Creek in Zone 4A and 6A related to management of Lake Mendocino and Lake Sonoma;
- maintenance activities on streams outside of SCWA authority for which no maintenance agreement exists;
- capital improvement projects (CIPs); and
- emergency activities and procedures.

A situation is considered an "emergency" if it is a sudden, unexpected occurrence involving a clear and imminent danger that demands immediate action to prevent or mitigate loss of or damage to life, health, property, or essential public services (Public Resource Code Section 21060.3). Although emergency situations will not be covered in the SMP, SCWA will make every effort to follow the guidance provided in the SMP when implementing activities under emergency conditions.

Routine stream maintenance does not include projects that would alter the designed flood conveyance capacity of a channel. Large construction projects and CIPs are not considered routine stream maintenance and are not included in the SMP. However, future CIPs may consider using, or adapting, the SMP to cover their maintenance needs and mitigation once their project becomes operational and requires maintenance.

1.6 Impact Avoidance and Minimization

The informed approach of the SMP not only requires a clear understanding of the location, extent, and specifics of maintenance activities; it also requires an understanding of the stream system's natural and aquatic resources. As described in this manual (Chapters 3 and 4), the SMP includes a method to inventory and assess each stream reach for its geomorphic, habitat, and species conditions. Each reach is also considered within its sub-basin and watershed context. Defining this baseline of what resources exist and processes operate at a given reach is fundamental to the SMP. Understanding these resources, their locations and how they interact informs an approach to avoid, minimize, and mitigate environmental impacts. Understanding these resources also influences how, where, and when routine maintenance activities should occur.

Chapter 5 *Pre-Maintenance Planning Approach and Impact Avoidance* describes how planning measures are taken to avoid and reduce impacts before any maintenance work occurs. The following maintenance principles were developed as guidelines to avoid and minimize environmental impacts of the program. Chapter 5 provides additional detail on how these principles are used.

1. No Unnecessary Intervention
2. Understand the System and Its Processes

3. Consider Adjacent Land Uses
4. Apply System Understanding to Maintenance Actions
5. Manage for Incremental Ecologic Improvement
6. Integrate Maintenance Activities towards Sustainability (to reduce frequency of maintenance)

When applied, these principals determine when action is needed, consider the natural function of the system, provide an understanding of local physical constraints, identify sensitive habitats, consider watershed processes, identify the maintenance activities needed at the reach and site scale, and seek solutions to minimize the on-going need for maintenance activities at a particular site or reach.

The maintenance activities described in Chapter 6 incorporate a range of measures to minimize undesired effects that could not be entirely avoided through the pre-maintenance planning approaches described in Chapter 5. These additional measures are described in Chapter 7 *Impact Reduction, Minimization Measures, and Best Management Practices (BMPs)*. Measures to protect natural resources, as well as "good-neighbor" policies were drafted to reduce the effects of maintenance activities. Table 7-1 organizes these measures and BMPs according to program activities and specific environmental resources. Taken together, the pre-maintenance planning measures described in Chapter 5 and the maintenance activity based measures described in Chapter 7 provide a comprehensive and integrated approach to avoiding and minimizing program impacts.

1.7 Program Mitigation

Through the use and application of avoidance and minimization measures and maintenance principals described above, potential impacts are greatly reduced. However, potential impacts that are not reduced through avoidance measures or project elements may require additional mitigation. The mitigation program for the SMP is described in Chapter 8.

The SMP's mitigation approach was developed through multiple discussions with agency representatives from the RWQCBs, CDFG, NMFS, USFWS, and the U.S. Army Corps of Engineers (USACE). Meetings were held with individual agencies and also together through group meetings of the IAWG. The SMP mitigation approach was also developed over the course of 3 years of interim permitting (2006-2008). During that period maintenance projects were developed, submitted for agency review, permitted, and implemented. The interim permitting period was used to demonstrate and refine program approaches, including the mitigation approach.

The mitigation planning approach follows a three-tiered system where mitigation opportunities are sought sequentially. Tier 1 mitigation is implemented on-site at the specific project reach where the maintenance work was conducted. Mitigation approaches on-site seek to enhance and restore the stream and aquatic functions and resources (in-kind) that were impacted through the maintenance activities.

Tier 2 mitigation is similar to Tier 1 mitigation in seeking in-kind mitigation in stream channels that had undergone maintenance. However, Tier 2 mitigation is applied at other stream channels, and is therefore not specifically on-site. Tier 2 mitigation is sought when there are no suitable opportunities for enhancement or restoration on-site at a specific channel reach and the next best opportunity is to pursue in-kind mitigation at a neighboring reach that does afford an opportunity for mitigation.

Tier 3 mitigation is off-site mitigation that provides compensating watershed based functions and values to SMP program impacts. Tier 3 mitigation addresses residual impacts from SMP activities that are not adequately avoided or minimized as described above or mitigated through Tier 1 and 2 mitigation actions. The Tier 2 and Tier 3 off-site mitigation address the temporary loss of Beneficial Uses and ecological functions and values during the time gap between SMP maintenance activities and when Tier 1 mitigation occurs, and the time when Tier 1 mitigation has become fully functional and the temporary impacts have been eliminated. Tier 3 mitigation provides restorative and mitigating watershed solutions for SMP impacts. Tier 3 mitigation is not only different in its geographic scope, it is also different in that it is not solely a SCWA effort, but is a collaborative effort with partnering agencies. This is accomplished through the off-site watershed mitigation program, whereby SCWA funds Tier 3 projects to be implemented with local non-profit agencies, municipalities, restoration organizations, creek groups, schools and Resource Conservation Districts (RCDs).

During the 2006-2008 interim period while the SMP was in development, four Tier 3 off-site watershed mitigation projects were successfully implemented with local RCDs, landowners, or non-profit agencies. These projects included headwater erosion control through stream fencing to protect streams from cattle grazing, erosion control activities at an active landslide to reduce downstream sediment yields into SMP flood control channels, and restoration and tree planting activities in the Upper Laguna watershed.

A key objective of Tier 3 mitigation is to reduce the overall necessity for channel maintenance. This is achieved through both erosion control and improved land use practices in upper watershed lands. Headwaters are a source for eroded sediments that are transported downstream to the many engineered, modified, and natural channels of the SMP. Reducing the sediment loading from headwater areas or upstream reaches is anticipated to reduce the need for subsequent downstream sediment removal activities.

The three-tiered mitigation approach ensures that mitigation is first and foremost directed to compensate for the impacts occurring at the specific project reach, then expands to consider all impacted reaches, and finally addresses the watershed as a whole. Chapter 8 provides details on the SMP's mitigation program.

1.8 Program Management

1.8.1 SMP Work Cycle

Implementation, administration and oversight of the SMP is described in Chapter 9. The SMP will be managed as an annual cycle of activities. Stream reconnaissance and assessment begins in late winter or early spring, followed by the development of the maintenance workplan. During the spring months, the year's maintenance projects are further refined and described, appropriate mitigation is identified, and the relevant regulatory agencies overseeing program permitting are notified. Projects are then implemented during the summer season, when the channels are at their driest. During the fall, and before the end of the year, an annual summary report of the year's maintenance, mitigation, and monitoring activities is sent to the permitting agencies.

1.8.2 Program Tracking

An important component in managing the SMP is to establish and maintain a comprehensive data management system. Data management is required throughout the SMP work cycle including: organizing the initial stream assessment and inventory; characterizing reach conditions; identifying maintenance needs; identifying sensitive habitats, weed populations, or other environmental considerations; documenting the implemented maintenance activities; documenting and tracking the implementation of restoration and mitigation activities; monitoring the on-going status of mitigation activities; and tracking all regulatory reporting requirements. The SMP database organizes all of this information and other data including reach assessment sheets, GIS mapping, habitat assessment sheets, and aerial photography. This SMP database provides a consistent and transparent way to monitor overall program activities, permitting compliance and track habitat and canopy development.

1.8.3 Program Reporting

As described above, at the conclusion of each year's maintenance season a summary report is developed, posted to the program website, and submitted to the appropriate regulatory agencies. This report includes: a summary of the year's maintenance projects describing what activities occurred and where; a description and confirmation of the restoration and mitigation activities implemented during the current year mitigation; a status and monitoring report of on-going mitigation activities initiated during previous seasons; and other program updates as necessary. The report may include additional information on project area conditions, activities employed, the effectiveness of certain activities, possible recommendations for future maintenance, or suggestions to improve the program's implementation and management.

1.8.4 Program Review

Following the submittal of the annual maintenance report, regulatory agency staff are invited to a review meeting to discuss the events, maintenance activities, and lessons learned over the past work cycle. Every 5 years, SCWA and the permitting agencies will review the SMP for its overall effectiveness. This review will include an assessment of maintenance activities conducted to date, BMPs employed, adequacy of the SMP Mitigation Program, SMP data management, adequacy of SMP adaptive updates and revisions, and overall program coordination and communication between SCWA and the regulatory permitting agencies. The program will be flexible to accommodate new resource information, management standards, and maintenance technology over time. As envisioned, the SMP will be a "living program" that is updated and modified as needed.

1.8.5 Regulatory Agency and Stakeholder Input

The SMP, the program manual, and the associated regulatory permitting, environmental compliance, and technical studies conducted to support the program were developed by SCWA during the period 2006-2009. During the program development period, close collaboration with regulatory agency representatives occurred through the IAWG. Numerous meetings were held with individual agencies and as a collective group. Guided field trips also occurred to show regulators the conditions at several sites in the Program Area. Regulatory agency staff members of the IAWG were instrumental in guiding the overall development of the program and providing direction on permitting, resource characterizations, impact avoidance, and mitigation approaches. Members of the IAWG reviewed the Draft SMP Manual thoroughly and provided detailed comments and suggested edits. In addition to regulatory agency guidance and review, SCWA presented the SMP at public meetings in 2008 with key watershed and governmental stakeholders to garner additional input. Additional public review and comment for the program occurred through the CEQA process and public commenting on the SMP EIR.

1.8.6 Program Commitment

Essential to SMP program success is SCWA's commitment to dedicate the required resources and staffing necessary to effectively administer, oversee, implement, and monitor the SMP. One of the key recommendations from reviewing other similar stream maintenance programs was the need for the agency developing and implementing the program to provide consistency, continuity, and a centralized manager in the operation of the program. SCWA has dedicated the resources necessary to ensure program success, including support of a full-time SMP Manager who will oversee implementation of the Manual and compliance with program permitting.

1.8.7 Program Documents and Materials

All documents and supporting materials used in developing the SMP, this manual, the program EIR, and the above referenced technical studies (Section 1.2) are housed in the SMP program library under the management of the SMP Manager and are available for viewing upon request. Most of the program documents and materials will be available for viewing through the program website at: http://www.scwa.ca.gov/about_your_water/stream_maintenance.php.

1.9 Program Partner – City of Santa Rosa

The SMP was developed in cooperation with the City of Santa Rosa (City). As described above, the City and SCWA have long standing easement agreements for SCWA to conduct maintenance on channels owned by the City. The City supports the flood management, natural resource protection, and recreation objectives of the SMP. In fact, there is strong agreement between many aspects of the SMP and the City's Citywide Creek Master Plan (City of Santa Rosa, 2007).

In addition to the easement relationship, the City provided an important partnering benefit to the SMP through providing valuable long-term sediment disposal opportunities. The North Coast RWQCB developed the Santa Rosa Nutrient Offset Policy in coordination with the City in 2006 to reduce net nutrient loading to the Laguna de Santa Rosa by 2011. The disposal of SMP sediments to suitable sites owned by the City (including the West College Pond and Place-to-Play sites) will provide an effective means to support the nutrient offset program. Additional information on the regulatory background for the nutrient offset program is provided in Chapter 2, Section 2.2.5 *Section 303[d] – Impaired Water Bodies and Total Maximum Daily Loads*. Additional information regarding the role of the City's sites for receiving disposed SMP sediment is described in Chapter 5, Section 5.6.4 *City of Santa Rosa Sediment Disposal Opportunities*.

The SMP EIR will include discussion and evaluation of programmatic impacts associated with using the nutrient offset program and coordinating with the City for SMP sediments to be disposed at City sites such as the West College Pond and Place-to-Play sites. For the SMP EIR, the City of Santa Rosa is recognized as a responsible agency under CEQA. In addition, a more specific work agreement is under development between SCWA and the City to more precisely describe the terms and conditions of SMP sediment disposal at City sites. This more specific agreement may result in the need for additional CEQA review and disclosure. Such additional CEQA review will occur as needed.

1.10 Program Permitting and CEQA/NEPA Compliance

As described above in Section 1.1, prior to the development of the SMP the permitting of stream maintenance activities was conducted on a project-by-project approach for all of the individual projects in a given year. This required abundant time, effort, and cost for SCWA and the regulatory agencies, and was inefficient in that most of the maintenance activities were routine and repetitive. Additionally, conducting projects individually limited the opportunities to conserve and protect natural resources through a broader watershed approach. For these reasons the SMP sought programmatic long term permits to provide regulatory compliance. The regulatory context for the SMP and the program's permitting approach are described in Chapter 2 *Environmental Regulations and Compliance* and summarized in the paragraph below.

SCWA is seeking approval of long-term permits for routine stream maintenance activities in channels and streams under the jurisdiction of the USACE, including Waters of the United States and special aquatic sites (wetlands) pursuant to Section 404 of the CWA. An Individual Permit (IP) will grant general authorization and set conditions for routine stream maintenance activities subject to jurisdiction of the USACE for a 10 year period. In addition, SCWA and USACE will be required to comply with requirements under Section 7 of the ESA for listed salmonids outside of Zone 1A and for other federally listed species not covered by the NMFS Russian River Watershed Biological Opinion. The RWQCBs will oversee compliance with Waste Discharge Requirements (WDRs) and Section 401 of the CWA through a 5-year permit with a defined process for renewal for another 5-year term. SCWA will also revise and update its existing Agreement for Routine Maintenance (ARM) with CDFG for stream maintenance activities in compliance with Fish and Game Code Section 1602, the Streambed Alteration program. In addition, CDFG will review the SMP for consistency with the California Endangered Species Act (CESA). The effectiveness of the overall program will be reviewed in 5 years as part of the permit renewal process.

CEQA compliance is triggered by the issuance of permits by state regulatory agencies including the RWQCBs and CDFG. CEQA is also triggered by the discretionary action of the Sonoma County Board of Directors (SCWA's governing body) approval of the SMP via adoption of the SMP Manual, the implementation of which may result in environmental impacts. Thus, SCWA is the lead agency responsible for complying with CEQA. Compliance with CEQA is being met through the development of an EIR for the SMP Manual. The EIR evaluates the environmental impacts of the maintenance activities proposed in the SMP Manual. The EIR was developed to address the needs of each regulatory agency to grant permits, as well as provide the necessary CEQA compliance to allow the Agency's Board of Directors to approve the SMP.

The issuance by USACE of a CWA Section 404 individual permit constitutes a federal action. Therefore, USACE must comply with NEPA. USACE will be the lead agency undertaking NEPA compliance. Similar to CEQA, The SMP Manual will provide the basis for developing the project description for NEPA compliance. NEPA compliance led by the USACE will meet environmental compliance requirements for permitting actions conducted by all federal agencies granting permits for the SMP, provided that the project description is the same for all issued permits (i.e., separate NEPA documents are not required to address USACE, USFWS or NMFS permits).

1.11 SMP Manual Organization

This SMP Manual is organized into the following chapters:

Chapter 1. Introduction and Program Summary provides an overview of the SMP including describing the program's purpose, area, channel types, maintenance activities, impact avoidance, mitigation, and permitting approaches.

Chapter 2. Environmental Regulations and Compliance describes the federal, state, and local regulations that are applicable to the SMP, reviews regulatory agencies and their permitting responsibilities for the SMP, and presents the program's compliance and permitting approach.

Chapter 3. Environmental Setting describes the physical and biological resource conditions in the Program Area that influence the SMP. This setting includes descriptions of topography, landforms, geology, hydrology, water quality, natural communities and vegetation, and wildlife in the Program Area.

Chapter 4. Channel Characterization describes the Program Area subwatersheds and provides detailed fact sheets for each of the engineered and easement engineered channels in the Program Area. For each maintenance reach key physical and biological conditions are described, photographs presented, and management needs and opportunities summarized.

Chapter 5. Pre-Maintenance Planning Approach and Impact Avoidance describes how planning measures are taken to avoid and reduce impacts are before any maintenance work occurs. This chapter presents the guiding principles and approach of the program to avoid and minimize environmental impacts.

Chapter 6. Maintenance Activities describes the primary program activities including sediment management, bank stabilization, and vegetation management activities, and secondary program activities of road maintenance, debris removal, fence repair, etc.

Chapter 7. Impact Reduction, Minimization Measures, and Best Management Practices (BMPs) presents additional measures to protect natural resources, provide good-neighbor policies, and other measures to reduce the effects of maintenance activities.

Chapter 8. Program Mitigation describes the SMP's 3-tiered mitigation approach, including the integrated watershed mitigation program to mitigate remaining impacts that were not effectively avoided or minimized.

Chapter 9. Program Management describes SMP administration and oversight including the implementation of the SMP annual work cycle, data management, regulatory agency notification and reporting, and program review.

Chapter 10. References provides a listing of the reference materials and documents used in the development of this SMP Manual and it's supporting planning studies.

Appendix A. Santa Rosa Nutrient Offset Policy – This policy describes a process for recognizing the City of Santa Rosa's nutrient reduction efforts and determining credit toward compliance with the 2011 zero net nutrient load requirement for the Laguna de Santa Rosa.

Appendix B. Sediment Sampling and Analysis Guidelines – This document describes the sediment evaluation procedures and criteria for disposal at various locations.

Appendix C. Watershed Partnerships Program Memorandum of Agreement: Sample Memorandum of Agreement and Grant Funding Application Form – This appendix provides a sample agreement between SCWA and the Sotoyome RCD to demonstrate a formalized work agreement between SCWA and a partnering agency within the Watershed Partnerships Program, that will provide watershed based mitigation for SMP activities. Appendix B also includes a sample application form that potential partners would use to apply for grant funding from SCWA.

Appendix D. Watershed Mitigation Project Descriptions – This appendix provides project descriptions for four watershed mitigation projects conducted in the interim period (2006-2008) while the SMP was in development. Project descriptions include photographs and information on the project location, partnering agencies, mitigation objectives.

(as observed in the lower portion of Hinebaugh Reach 2 and Reach 1). Depending upon flood conditions, backwatering effects from the Laguna continue upstream to the Highway 101 crossing, as observed during flow events in the fall of 2007. Backwatering from the Laguna causes sediment deposition in the lower reaches of Hinebaugh Creek (see reach sheets for *Hinebaugh 1, 2, and 3*). Bars within the channel and sections with little riparian canopy creates conditions where cattails thrive. The cattails encourage additional entrapment of fine sediment and impede flow through the channel. Many of the reach sheet photos for Hinebaugh Creek illustrate this problem. Two large reach-scale sediment removal projects were conducted at Hinebaugh Creek Reaches 1 and 2 in 2007 and 2008. The channel was cleared of deposited sediment and cattails and a low-flow channel was excavated.

Suitable spawning habitat for steelhead may exist in the upper tributaries to Hinebaugh Creek, such as Crane Creek. However, to date no steelhead have been observed in the upper reaches during SCWA surveys although other cold water fish such as sculpin have been observed. As shown in Table 7-3, reaches of Hinebaugh and Crane creeks are identified as supporting migratory habitat for steelhead. The subbasin also supports habitat for California tiger salamander.

Copeland Creek

The headwaters of the Copeland Creek subbasin (5.1 sq. mi.) extend to the east beyond the city limits of Rohnert Park and rise up the slopes of Sonoma Mountain to a peak elevation of 2,463 ft. This headwater area provides the source areas for runoff, groundwater recharge, and sediment yields transported downstream. West of Petaluma Hill Road, were elevations and slope decrease across the alluvial plain, Copeland Creek becomes a straightened engineered flood control channel (Figure 4-30). Snyder Lane marks a shift toward a more depositional channel environment with cobbles and pebbles being deposited upstream of Snyder Lane and finer sand and silt materials depositing downstream of Snyder Lane.

Sediment deposition is observed throughout Copeland Reaches 1-5. In Reach 5, near the Snyder Lane crossing, sediments consist primarily of gravels (course sands, pebbles, and small cobbles). These coarser sediments are organized into longitudinal bar features, with narrow low flow channels between the bars. Of note, the sediment bars near the Snyder Lane Bridge aggraded over 1 ft. in height during the storm events of early January 2008. Moving downstream to Reach 4, sediment texture transitions to finer materials including medium sands and finer silts. As this occurs, the depositional patterns change from the defined gravel bars upstream to a more homogonous filling of the entire channel width. SCWA conducted a reach scale sediment removal project (including excavation of a low-flow channel) at Copeland Creek Reach 4 during 2008.

Downstream of Reach 4, SCWA had previously excavated a low-flow channel during previous sediment maintenance activities at Reach 3 in 2003. As described in the reach sheets for *Copeland 1, 2, and 3* benches and bars have established adjacent to the low-flow channel. In conjunction with the riparian corridor of lower Copeland Creek, these features provide channel complexity, habitat improvement, and an important migratory corridor for fish that pass through the engineered Copeland Creek reaches toward upstream spawning sites. Upper Copeland Creek supports spawning and rearing habitat for steelhead in its upper reaches (Table 7-3). The Copeland Creek channel provides important migratory corridor from the Russian River and Laguna, to the upper Copeland Creek headwaters. The low-flow channel features will improve sediment transport functioning and improve channel complexity for the benefit of juvenile salmonids. Vegetation within Copeland Creek is dense, ranging from riparian forest in Reach Copeland 2 (Figure 4-40) to riparian woodland providing 75% canopy coverage in reaches Copeland 4 and 5.

South Fork Copeland Creek (Figure 4-40) primarily conveys runoff from surrounding residential neighborhoods and joins Copeland Creek at Reach Copeland 3. As noted in the reach sheet, this drainage channel is likely a borrow ditch from construction of the adjacent railroad berm. Poor water quality in the channel, such as highly turbid water and floating oils, indicate the influence of the surrounding development on habitat quality. This channel may provide an important water quality and sediment filter for runoff from drainage areas south of Copeland Creek and between Snyder Lane and Highway 101.

Upper Laguna Channel

The Upper Laguna drainage area forms the southernmost divide between the Russian River and Petaluma River watersheds. The Upper Laguna channel daylights from a culvert at Liman Way and Myrtle Avenue in Cotati. Headwater areas further upstream of the daylighted culvert are disconnected due to development, but flows contained in the uppermost reaches (Reaches 6 and 7) are still supplied by underflow through the alluvial plain and urban surface runoff. Sediment clearing in reaches *Laguna 6 and 7*, as described in the reach sheets, has improved flow conditions and provided opportunities for community involvement in riparian plantings, such as organized by the Cotati Creek Critters organization for example. The Cotati Creek Critters organization is one of the Watershed Partners who have participated in SCWA's watershed mitigation and grant funding program (see Chapter 8 *Program Mitigation*). The continued nurturing and planting of the riparian corridor in these upper reaches will hopefully reduce the need for additional cattail removal and bank stabilization projects.

In Reaches 4 and 5, the channel is wider and more sinuous than Reaches 6 and 7 (Figure 4-41). The increased available width in the channel encourages establishment of a low flow channel and a riparian overstory. Approaching Highway 101 at the lower end of Reach 4, the channel is concrete lined with vertical walls. Patches of riparian vegetation on the banks and in the channel (cattails) provide varying levels of habitat.

The channel gradually widens as it continues to flow downstream, most noticeably at Reach 3, west of Highway 101. The channel is slightly wider than the reach upstream and a low flow channel and pools have established throughout the reach. Fine sediments are abundant and because of limited shading and the gentle channel gradient (see Figure 4-39), cattail growth is widespread. During moderate storm events the Laguna routinely backwaters upstream into Reach 3.

Washoe and Copeland creeks enter at the lower end of Reach 3. The reach of Washoe Creek maintained by SCWA is likely a remnant of the original channel's alignment. Headwater flows to Washoe Creek are redirected to Gossage Creek at Derby Lane, north of Highway 116. The remnant channel reach (*Washoe 1*) primarily functions to convey runoff from agricultural activities surrounding the area. Backwatering influences from the Laguna are felt in this reach as well.

In Laguna Reach 2 the channel transitions from riverine processes to a more still water or lagoonal environment. This reach of channel was designed with the capacity to convey flow from the upper drainage area, as well as the Copeland, Gossage, and Hinebaugh drainage areas. The channel widens even further at Reach 1 where the Bellevue-Wilfred flows are received. Water is dispersed widely across the channel and the bed is layered with silts and clays. Ludwigia occurs commonly throughout the lower portions of the Upper Laguna channel. In some locations, riparian cover over the channel assists in suppressing growth of ludwigia and cattails.

The Upper Laguna channel supports habitat for steelhead (migratory corridor), California tiger salamander, western pond turtle, and some special-status plants. Unlike most of the major tributaries to the Upper Laguna system which flow from the east, the Gossage Creek tributary joins the Upper Laguna system, flowing from the south and west. Gossage Creek also supports migratory habitat for steelhead. Gossage Creek has experienced ludwigia encroachment in its lower reaches. Improved riparian corridor management to prevent growth and distribution of cattails and ludwigia would ensure this habitat is protected and improved in the future. Gossage Creek has also had two bank stabilization projects conducted by SCWA in recent years (2006-2008).

4.3 Petaluma River Watershed (Zone 2A)

The Petaluma River watershed is located in southern Sonoma and northern Marin Counties. Approximately 112 square miles of the 146 square mile watershed are located in Sonoma County. The City of Petaluma and the unincorporated community of Penngrove, as well as, a portion of the Town of Novato and outlying unincorporated areas are located in the Petaluma River watershed.

Elevations in the watershed range from sea level at San Pablo Bay to about 3,000 feet MSL at Sonoma Mountain. Major tributaries to the Petaluma River in Sonoma County include Lichau Creek, Wiggins Hill Creek, Corona Creek, Capri Creek, Lynch Creek, Washington Creek, McDowell Creek, Thompson Creek, Adobe Creek, Ellis Creek, and San Antonio Creek, which forms the border with Marin County (Figure 4-42). The lower 12 miles of the Petaluma River flow through the Petaluma Marsh. The river ultimately empties into the northwest portion of San Pablo Bay. Tidal influence extends approximately 14 miles upstream of San Pablo Bay, to near the confluence of Lynch Creek above downtown Petaluma. The Petaluma River is one of the few remaining rivers in California that continue to support commercial river traffic.

The majority of the Petaluma River watershed is in non-intensive agricultural production, including oat hay production and dairy cattle and sheep grazing lands. Vineyard development has occurred throughout the watershed from the 1990's to the present, including on Sonoma Mountain and along Lakeville Highway. Urban runoff from the City of Petaluma, which covers approximately 14 square miles, is directed to the lower Petaluma watershed.

to illustrate the Maintenance Principles are incorporated into the annual Stream Assessment process described in Chapter 9 *Program Management*.

5.3 Sediment Management Approach

5.3.1 Framing Considerations

Five key considerations frame the context and approach for sediment management activities.

- **The natural function of streams is to convey sediment from headwater source areas (or upstream in-channel source areas) to downstream reaches, lowlands, or basins where the sediment ultimately deposits.** In all streams, sediments are variably eroded, transported, or deposited. The movement of sediment along the stream system represents a beneficial natural function. Chapter 3 describes geomorphic and sediment transport processes in the Program Area. However, it is also recognized that natural sediment transport processes are strongly affected by historic and current land use conditions, urban development, past engineering and alterations to the channel network, and other modifications. As a result of these influences, sediment transport processes and loadings may be augmented or depleted depending upon the reach. In a system already largely impacted through such conditions, additional maintenance is required to manage sediment and ensure the protection of streamside land uses.
- **Sediment transport is an inherently dynamic process.** Because of this dynamism, target conditions for sediment transport should not be stable or static, but should reflect some degree of variability and include the possibility of episodic high-magnitude events. For sediment management, target outcomes should reflect an acceptable range of conditions rather than a static prescribed form.
- **Sediment loading and vegetation growth are intimately related in a feedback loop.** Sediment supports the growth of vegetation within and along the channel, and vegetation in turn benefits habitat quality by shading the channel, reducing water temperatures, and improve oxygen exchange in the water column (NMFS, 2008). However, excessive vegetation growth can reduce flood conveyance capacity; contribute to elevated nutrient loading, ultimately decreasing water quality; increase sediment deposition rates; and reduce habitat quality and complexity by creating shallow, diffuse flow conditions across the channel bottom.
- **Sediment accumulation can reduce the channel's ability to convey floodwaters.** This poses a particular challenge where streams that were historically broad, or part of a braided multi-channel system, are now confined into a single channel. Historically, such systems deposited their sediments across wide floodplains. Now, such confined systems may be inherently depositional, depending on channel hydraulics and the balance of slope vs. cross sectional area. In engineered systems, sediment is likely to deposit in reaches with relatively gentler gradients or where the channel cross section is wider than necessary to convey expected loads. SMP stream managers recognize that some degrees of

sedimentation or erosion will occur in a healthy stream—what is essential for stream management is to identify and address reaches where deposition or erosion are excessive. Sediment management triggers described below provide guidance on when sediment management should be initiated.

- **Accumulated sediment can obstruct infrastructure such as culverts and bridge underpasses.** This can lead to backwater conditions that further reduce transport, alter habitat, contribute to flooding, and potentially cause damage to instream and channel bank structures.

5.3.2 Sediment Management Goals

Consistent with the Maintenance Principles and Framing Considerations described above, the goals of sediment management for the SMP are to:

- understand the way each reach functions as a sediment conduit within its stream, its subwatershed, and its land use context;
- identify an appropriate maintenance target condition that balances flood protection needs, economizes maintenance activities, and avoids and minimizes environmental impacts for that reach;
- contribute to improvement of water quality conditions through nutrients removal, invasive plants removal, and hydraulic improvement; and
- implement treatments that will enhance the stream's function toward the desired condition while minimizing the need for repeat maintenance.

Target conditions for each reach will be identified according to management needs, reach functioning, and other opportunities and constraints. The reach and its host stream will be managed to maintain and enhance sediment conveyance, water quality, and habitat.

Sediment will be managed for the following specific outcomes.

- a general balance between channel aggradation and channel erosion;
- adequate flood conveyance capacity;
- preservation and enhancement of beneficial instream bed forms and habitat features (including LWD) that support in-channel complexity, diverse cover, and local/micro habitats to the extent feasible;
- development and preservation of the desired vegetation condition for the reach.

To achieve these goals without impacting stream function, sediment management will be implemented incrementally. This will prevent sudden, drastic alterations in sediment load within individual reaches, which could accelerate further aggradation or incision. Incremental implementation also allows time for monitoring, evaluating channel conditions, and adaptively adjusting the maintenance approach as needed. The incremental maintenance approach has a spatial component and a time component, in that activities will occur in focused reaches at a given time and not throughout an entire stream system in any given year. Therefore, stream maintenance activities for particular reaches will be prioritized annually with only the reaches in most need being treated.

5.3.3 Sediment Management Triggers

In general, sediment management or removal activities are appropriate when any of the following conditions applies.

- The channel is systemically aggrading such that channel capacity is at risk. The degree to which channel capacity has been reduced is determined based on visual assessment (during dry season and wet season conditions), cross section comparisons to the as-built channel condition, and any past record of flooding conditions.
- Accumulated sediment is covering culvert outfalls, drop-inlets in V-ditches, or filling box culverts, threatening to cause flooding.
- Sediment is accumulating in a way that supports excessive vegetation growth, threatening channel capacity or creating undue roughness.
- Sediment accumulation is impeding fish passage.
- Significant bed erosion is occurring, particularly where a migrating nickpoint reflects headward incision.[2]
- Instream structures designed to direct flows for flood management are causing excessive sediment deposition or bed or bank erosion.
- Bar surfaces that would support groundwater recharge have aggraded to the point that they can no longer be effectively inundated for a sufficient duration to recharge underlying groundwater stores. The grading down of bar surfaces would occur in consideration of the presence of an existing low-flow channel and what is the width, depth, and orientation of such a low-flow channel.
- Instream hardscape requires sediment removal to maintain as-built functions.

The need for sediment management action is unlikely if none of these trigger conditions are present.

[2] In reaches with significant bed erosion, particularly those where a migrating nickpoint and headward incision occur, grade control may be needed in addition to, or instead of, sediment management. In some cases, it may be possible to reduce bed erosion by removing excess sediment. The key to selecting the appropriate treatment will be to identify the cause of the erosion. The need for grade control is most likely to be indicated when bed erosion results from consistently excessive flow volume or velocity, which is typically associated with changes in upstream land use patterns. Grade control may also be an appropriate treatment for erosion resulting from turbulence downstream of flow-constricting infrastructure such as bridges or culverts. Grade control installation is typically outside the scope of normal maintenance activities, and is not included in this SMP Manual.

5.3.4 Design Guidance for Sediment Removal Projects

The guiding questions and assessments described above are used to understand the channel's function and design an appropriate sediment removal project that achieves flood management and ecosystem objectives while minimizing impacts. The additional issues and questions below are used to refine the maintenance project approach and provide design guidance. The following issues will be recognized and addressed to clarify the key processes and help guide the design process:

- Did the reach in question historically function as a depositional zone? Or, was the reach historically more of a transport zone and only recently has it become more depositional? Comparison of past channel cross sections, photos, and recorded observations (as available) should be used to describe the historical condition. Based on the historic trend of the reach, the extent of sediment removal can be targeted for the project.
- Is sediment accumulating throughout the reach, depositing broadly across the entire channel cross section as a homogenous sediment wedge? Based on the situation, the need and size for an instream low-flow channel can be refined.
- Is sediment collecting in particular locations along the longitudinal profile such as the upstream and downstream ends of crossings and culverts? Are such culverts undersized or otherwise designed in a way to encourage sediment deposition instead of transport? Known collection spots are used to target sediment removal locations.
- Is sediment being deposited in particular features within the channel such as mid-channel bars, sediment benches and wedges along the edge of the channel, or in sinuous alternating bars along the longitudinal axis? Understanding these situations allows the sediment removal project to work with natural processes and to preserve natural forms as much as possible.
- What is the dominant texture of the sediment accumulating in the reach and is there a pattern observed? Sediment patterns indicate the depositional environment and can be used to refine the extent and location of sediment removal activities.
- What is the net rate of sedimentation at the reach (either measured as a depth or a volume over a certain period of time)? Understanding the sediment rate will inform how frequent sediment removal activities shall occur.
- Is there an existing low-flow channel operating within the wider channel cross section?
- If a low-flow channel is present, is this channel adequately transporting sediment under medium and lower flow conditions through the reach? Monitoring the existing low-flow channel is useful if adjustments are necessary to either enlarge or deepen the low-flow channel.

The planning considerations described in the sections above for sediment removal projects are illustrated by recent sedimentation events and maintenance activities at Copeland Creek (Figure 5-3). Storm events during 2005-2008 deposited abundant sediment at the Snyder Lane crossing of Copeland Creek. This was punctuated by a storm in January 2008 that raised the bed with 1.5 ft of sediment and further reduced the culvert capacity beneath Snyder Lane in a single event. The reduction in channel capacity increased overbank flooding potential during the remainder of the 2008 season.

This reach of Copeland Creek is a known migration corridor that allows steelhead to access potential spawning habitat further upstream in the watershed (NMFS, 2008). However, the heavy deposition that reduced the crossing at Snyder lane and filled the channel with sediment also created an aggraded bed with diffuse flow and very low water elevations which reduced the reach's functioning as a migration corridor. This situation of reduced migration capacity due to abundant sediments and shallow/diffuse flows at Copeland Creek is also described in the recent Russian River Watershed BO (NMFS, 2008).

The maintenance project undertaken in the fall of 2008 removed sediment from the reduced crossing and impacted channel, as shown in photo (d) of Figure 5-3. The maintenance project also included the creation of a low-flow channel to maintain an active channel that could support fish migration and the transport of fine sediments under lower flow conditions. The 2008 maintenance project at Copeland Creek nicely demonstrates all of the SMP Maintenance Principles. The work was necessary in light of increased flooding. System dynamics, adjacent land uses, and the reaches environmental resources were all considered in designing an appropriate (and not excessive) project that achieved flood management goals while also enhancing habitat conditions.

5.4 Vegetation Management Approach

5.4.1 Framing Considerations

Five key considerations frame the context and approach for vegetation management activities.

- **Riparian vegetation provides physical stabilization for bank and terrace surfaces through the growth of root structure.** In addition to the structural benefits provided by roots, vegetation also contributes to bank stability by helping remove excess soil moisture, which can contribute to slumping and other types of bank failure. This represents an important nexus between vegetation management and bank stabilization efforts.
- **Riparian vegetation benefits instream habitat by shading the channel, drawing subsurface water up, lowering water temperatures, limiting in-channel emergent vegetation, and providing LWD.** Cooler water temperatures are preferable for cold water species, such as salmonids (NMFS 2008). Shading of the channel can also hinder the growth of instream emergent vegetation, in turn reducing the need for future instream vegetation management. Riparian vegetation pulls subsurface moisture up via the transpirational stream, in some cases, keeping water in the channel. It also provides cover, forage, and breeding habitat for a variety of birds and other wildlife that use the streambank area.

- **Invasive species may limit the success of native, slower-growing vegetation and can degrade habitat quality over time.** Because many invasive species (both native and non-native) grow quickly, they often out-compete non-invasive native species. This may occur to the point that entire channels are filled with fast-growing, invasive vegetation further degrading habitat quality.
- **Excessive vegetation growth can decrease a channel's flood conveyance capacity.** This occurs in three ways. First, excess growth of instream and bank vegetation can obstruct the channel by reducing its cross section and conveyance capacity of the floodway as a whole. Second, vegetation increases bed and bank friction or hydraulic roughness, resulting in energy losses, turbulence, decreased capacity, and leads to an increased threat of flooding. Third, increases in hydraulic roughness can encourage further sediment deposition as flow velocities slow. This effect is illustrated in photos in Figure 6-12 and 6-14 through 6-16.
- **Establishing adequate flood protection may require aggressive vegetation management.** In areas where creeks are closely bordered by developed land uses or agriculture, the increased risk of flooding created by excess vegetation growth may be unacceptable, and it will be important to identify the threshold at which vegetation must be managed in each reach to provide adequate flood protection and ensure the safety of the community.

5.4.2 Vegetation Management Goals

Consistent with the framing considerations presented above, the goals of vegetation management are to:

- ensure that adequate flood conveyance capacity is maintained; and
- develop a mature and complex riparian canopy and corridor that offers substantial habitat, shading of the creek, and aesthetic value while minimizing future understory maintenance requirements.

In most channels, meeting these goals will require a balance between habitat and flood protection needs. Although it is possible to identify an ideal vegetation configuration, it may not be possible to achieve this condition in all reaches of all channels. As described in Chapter 3 *Environmental Setting*, a range of channel vegetation conditions is observed in the SMP Program Area. Figure 5-1 synthesizes this range of conditions into a spectrum of channel characteristics, each with varying ecologic and habitat quality.

Figure 5-1 provides a basis for establishing a realistic target for incremental vegetation and habitat improvement for each reach. For example, Reach C in Figure 5-1 has some riparian vegetation but almost no canopy. Reach C could be managed or restored toward the conditions of Reaches D or E (more large trees and some canopy) with the right management activities. However, it is unrealistic to expect that Reach A could become like Reach G. In other words, the vegetation maintenance target for each reach is informed by an understanding of what potential conditions can be achieved. Vegetation should be managed to bring the reach as close as possible to its target condition. Over the longer term, management approaches will actively explore ways of improving the target condition of each reach, and to keep improving along the vegetation and habitat spectrum.

Within this context, vegetation will be managed for the following outcomes as appropriate for reach specific conditions:

- to develop riparian woodland/forest canopy closure;
- to encourage native vegetation and discourage nonnative vegetation, particularly invasive species;
- to control emergent vegetation in the channel;
- to minimize flow obstructions; and
- to improve bank stability.

Table 5-1 presents summary information for riparian canopy cover conditions for the engineered flood control channels in the Program Area. This summary is based on detailed vegetation mapping conducted for the SMP during 2006-2008. Channels with less than 25% canopy cover are most common and represent the largest amount of stream length. Channels with more than 75% canopy cover are least common. The table indicates that a good opportunity presents itself for SCWA to continue with its vegetation planting program, and selective pruning techniques to increase the degree of canopy cover over a greater portion of the engineered flood control channels.

Table 5-1. Summary of Program Area Canopy Cover Conditions

% Canopy Cover	Number of Reaches	Length (mi)
up to 25%	84	27.2
25 to 75%	69	17.4
75 to 100%	3	0.28
totals	156	44.9

Note - 44.9 mi total stream length only includes reach segments in engineered and easement-engineered channels that have some riparian forest vegetation. Total stream length for all engineered channels is more than 76 miles. About 31 miles of engineered channels have no measurable riparian cover.

5.4.3 Vegetation Management Triggers

In general, vegetation management is appropriate when any of the following conditions occur:

- Vegetation growth is significantly decreasing flood conveyance capacity, particularly where infrastructure or adjacent properties are at risk (photos in Figures 6-12 and 6-14 through 6-16 illustrate channels with diminished conveyance capacity due to excessive vegetation growth);
- Invasive nonnative plants are reducing the success of native vegetation; or

- Vegetation management offers good opportunities to improve habitat value for fish and wildlife.

The decision to remove, thin, or preserve individual trees will be made in the field by SMP field staff familiar with regional and wetland ecology. Consideration for individual tree removal or thinning will be based on several factors including:

- What is the degree of blockage across the channel and where is the tree located in the channel?
- What is the type and age of the tree? Are there a lot of these trees already in the channel reach? Are there better trees to preserve?
- Can the individual tree be pruned or thinned (before consideration of removal) to provide the necessary conveyance capacity?
- Does the tree under consideration provide shade or other habitat benefits?
- Does the tree under question provide longer-term canopy development or riparian corridor benefits?

The rationale to either thin, prune, or remove trees will be based on addressing these questions above. Answering these questions requires the oversight and guidance of a biologist or arborist that is familiar with the Program Area's vegetation and knowledgeable of channel botanical conditions.

The planning considerations described in the sections above for vegetation management projects are illustrated through comparative photographs from Santa Rosa Creek (Figure 5-4). Photo (a) from Figure 5-4 shows Santa Rosa Creek in 1997 before the SMP vegetation management approaches were used. Up to that time, the reach was managed to keep bank and bed vegetation to a relative minimum to preserve an open trapezoidal channel shape without much hydraulic roughness from bank vegetation. In contrast, photo (b) from Figure 5-4 shows the same reach on Santa Rosa Creek in 2007. Over the course of 10 years, and with a more habitat sensitive approach to vegetation management as described in this manual, vegetation was selectively preserved in Santa Rosa Creek. Arroyo willows were removed and the taller alders were naturally recruited and pruned to provide a riparian canopy. Additional recruitment of aquatic plants including sedges and grasses have contributed to the understory development. The 2007 condition shown in photo (b) of Figure 5-4 represents a channel that balances flood management needs with improved natural resource conditions, a central objective of the SMP. Additional details on the SMP's vegetation management activities are provided in Chapter 6, Section 6.4. Additional photos of Santa Rosa Creek are shown in Figure 6-11.

Design guidance for the SMP's vegetation planting program is provided in Chapter 8 *Program Mitigation* as it is related to the program's mitigation and restoration approach.

6.3.1 Sediment Sources

Building on the understanding of key processes described in Chapter 3 and the reach conditions presented in Chapter 4, three primary mechanisms are observed to explain abundant sedimentation in certain Program Area reaches. These primary mechanisms are watershed sediment sources, channel geometry, and flow conditions (hydrology and hydraulics).

In general, sediment is delivered to a reach as transported material from upstream areas. This source material may be derived from upland areas (including landslides, gullies, or sheetwash erosion) or may be eroded directly from the channel bed or banks upstream. Upstream sediments are transported downstream through the drainage network of joining tributaries.

In terms of channel geometry components, gradient, channel width, and depth of flow are the key causal factors. A low gradient stream may favor sediment to fall out of suspension or result in bedload transport. A wide channel cross section may cause the dispersion of flows and reduced flow velocities resulting in net deposition and bed aggradation. The lack of a defined channel that can contain small and medium sized flows (approximately less than the 2-year return interval) within the broader cross section can also be a cause for sedimentation. In such cases, shallow diffuse flows are not adequate to transport sediment downstream. This results in deposition and aggradation across the entire width of the channel bed. This process is observed repeatedly in several of the channels in the Program Area (refer to Chapter 5, Figure 5-3). Use of two-staged low-flow channels to improve fine sediment transport and reduce deposition is described below in the sub-section *Creation of Two-Stage Low-Flow Channel*.

Hydrologic processes including intensity and duration of precipitation, infiltration, runoff, shallow throughflow, and recharge determine the water balance of the watershed and how much flow is carried in the channel system. Such hydrologic processes determine the magnitude, duration, and frequency of flows arriving to a reach. The in-channel hydraulic conditions will determine whether sediment will be deposited in a given reach, be eroded from the reach, or be transported through the reach. Sediment transport processes are complex and a combination of any or all three of these processes could occur in a given reach.

As described in Chapter 3 (Sections 3.2 through 3.4) there are certain locations in the Program Area where, due to sediment sources, channel geometry conditions, and hydrology/hydraulic conditions, abundant sedimentation is both expected and observed. At such locations channel maintenance activities, as described below, will need to be implemented.

6.3.2 Reach Scale Sediment Removal

As illustrated in the channel assessments and maps of Chapter 4, channel reaches in the Program Area have been typically defined at their upstream and downstream ends by hardened crossings or culverts. When in-channel deposited sediment aggrades throughout an entire reach such that flow capacity is significantly diminished, reach scale sediment removal may be required.

Individual reach scale projects are generally 1,000 to 3,000 feet long and might typically involve the removal of between 2,000 and 7,500 cubic yards of sediment, with yearly totals for multiple projects typically ranging between 10,000 and 25,000 cubic yards. Following a particularly wet year (or series of wet years) up to five or six reach scale sediment removal projects might occur. Following an average hydrologic year, three or four reach scale projects might be planned and implemented though some years may not require any. In 2007, there were three reach scale projects, and four reach scale projects were implemented in 2008. A summary of sediment removal volumes and reach lengths for the 2006-2008 maintenance years are presented in Table 6-1.

The Hinebaugh Creek and Copeland Creek sediment projects implemented in 2007 and 2008 exemplify reaches that had experienced significant sediment accumulation in recent years. In these channels, conveyance capacity was reduced, and local flooding resulted. Reach scale sediment removal projects were designed and implemented to address deposition and increased flooding risk along these specific reaches (Figure 6-1).

A reach scale sediment removal project will typically involve the following activities:

- mechanized sediment removal along a 1,000–3,000 ft. reach of channel;
- removal of approximately 2,000 to 7,500 cubic yards of sediment, with average depths of removal between 1.0 to 2.5 feet from the channel bed;
- installation of temporary access ramps if/as needed;
- use or designation of targeted sediment collection areas;
- removal of vegetation from channel bottom;
- removal or limbing of selected trees growing at the toe of channel banks;
- creation of a low-flow channel to convey flows and transport sediment for smaller sized flow events; and
- dewatering through the installation of temporary coffer dams if/as needed.

These activities are further described below. Note that reach scale sediment removal projects integrate several vegetation management actions. Vegetation activities closely associated with sediment removal projects are introduced below in this section, and described in more detail in Section 6.5.

Mechanized Sediment Removal

Aggraded sediment is removed with a long-reach excavator, bulldozer, scraper, or front loader. When using a long-reach excavator, sediment is excavated from the channel bed, collected, and removed with the excavator usually positioned on the maintenance roads located along the top-of-bank. If the channel shape or the presence of large mature vegetation along the channel banks prevents working from the top-of-bank, then the excavator may be positioned lower on the channel banks using an access ramp. Use of access ramps are described below. When working near the upstream or downstream limit of the reach the excavator may be positioned on the stream road crossing or culvert.

Once excavated, sediment is either placed directly into dump trucks parked on the access road or stockpiled into central locations along the channel and then subsequently lifted to the adjacent dump trucks. Figure 6-2 demonstrates the use of excavators, front loaders, and bulldozers in removing sediment from the 2007 reach scale project at East Washington Creek. Approximately 1,432 cubic yards of accumulated sediment (average depth 1.2 feet) was removed during this project and the before and after photos of the site are presented in Figure 6-2a and 6-2f.

BMPs and avoidance and minimization measures will be applied to sediment removal activities based on equipment used, site conditions, and access to the site. If equipment is operated in such a way that loose sediment may possibly enter the active channel, erosion control fabric will be installed at the toe-of-slope or along the edge of the active channel to avoid delivery of any dislodged sediment into the channel and/or low-flow channel. If equipment is used within the channel, or if activities conducted from top-of-bank may affect the active channel, the work area will be isolated from flowing stream segments using silt fences, wattles, and/or cofferdams (see the *Dewatering* sub-section below for more details). Additional BMPs are identified in Table 7-1 and will be applied as appropriate to all sediment removal projects.

Channel Access and Staging

Access to the project site and staging of equipment and vehicles will take place on existing access roads adjacent to the channel. The engineered channels have at least one access road running along the top-of-bank on one side of the channel. More often channels have an access road on either side of the channel. Where feasible, work is conducted from the north side of the channel to avoid needing to remove vegetation (and the accompanying shade reduction) from the south side. Many of the Program Area channels also have additional access roads at a lower level along the banks, and not just at the top-of-bank location.

When the channel shape, bank height, or the presence of large mature trees prevents the use of the top-of-bank access roads, an access ramp (earthen or hardened if already existing) will be used to move the equipment lower on the bank of the channel, or move the equipment into the channel. A pad may be placed halfway down the bank slope so that an excavator can work from that point, reaching down to the channel bed to collect sediment and then placing the sediment in a dump truck above on the access road. This approach could be used in locations where placement of a pad is feasible or where there is a low-flow access road (e.g., lower Santa Rosa Creek where the bank has a built-in shelf above the channel bed).

When necessary, sediment removal activities can be conducted from within the channel bed. This approach is favored where top-of-bank or side-bank access is unavailable, or would require unnecessary damage to trees along the riparian corridor. In-channel sediment removal activities would only occur under dry channel conditions. Scrapers, skid loaders, bulldozers, and smaller Bobcat® type loaders are used when working directly in the channel bed (Figure 6-3).

Access ramp locations are selected to avoid impacts to vegetation, while providing efficient, safe equipment access to the work area. If used, access ramps are temporary and will be regraded and replanted following the sediment removal activities. The ramps will be seeded with native grasses and erosion control fabric will be installed.

All removed sediment, whether working from top-of-bank, mid-bank, or in channel will be placed in 10- or 20-cubic-yard dump trucks located on the access road or within the staging area. As appropriate, exposed soil on streambanks that remains after sediment removal activities will either be seeded with grass and covered with erosion control fabric or planted according to the on-site restoration planting designs described in Chapter 8 *Program Mitigation*.

Targeted Sediment Removal Areas

As a means to reduce maintenance needs and impacts associated with removing sediment from an entire reach length or creating multiple access ramps, targeted sediment collection areas may be identified at appropriate locations. Such focused sediment removal areas are identified for reaches with chronic and abundant sedimentation. Typically this might involve a 100 ft section of channel immediately upstream or downstream of a site where sediment is known to collect, such as a bridge or culvert. This is observed at several locations including a number of sites in Rohnert Park such as the Wilfred Channel downstream of Snyder Lane, Copeland Creek downstream of Snyder Lane, and Coleman Creek upstream of Hillview Lane (Figure 6-4). Targeted removal areas use locations with easy access and limited vegetation near a crossing. The channel will be excavated to near as-built conditions locally within the channel footprint. This excavated zone will capture future deposited sediment and continue to provide easy access for removal.

Vegetation Thinning or Removal for Sediment Removal Projects

Sediment removal projects often require some degree of vegetation removal or thinning in order to access a project site or begin conducting work on the channel bed or bar surface. Cattails, willows, Himalayan blackberry, and various non-native grasses are the plants most typically thinned or removed in combination with reach scale sediment removal projects.

Whenever possible, access points will be sited to avoid trees and shrubs and will take place in locations where vegetative cover is minimal. If vegetation must be removed to provide short-term equipment access, removal of non-native species or less desirable species such as arroyo willow (*Salix lasiolepis*) will be prioritized. Other vegetation characteristics such as age/size of tree, local vegetation diversity, and if the vegetation is providing a particular habitat value will also be taken into consideration when prioritizing removal of vegetation for channel access. In areas where routine or repeated sediment removal is needed (once every three years or more often), an access route to the channel will be maintained free of woody trees and shrubs. These access points will be stabilized with native grasses and fabric. To reduce effects on habitat quality, the width of the access point should be the minimum needed to provide safe access for equipment. Please see Section 6.5 for additional discussion regarding tree removal.

For in-channel vegetation removal prior to conducting sediment removal activities, an effort will be taken to maintain and not remove vegetation that provides channel stability, anchors in-channel bars, or provides habitat benefits through the presence of large woody debris (LWD). Vegetation located on in-channel bars is particularly important at the bar's downstream tip (head) and/or along the bar's periphery. Allowing this vegetation to remain also provides shading benefits to the adjacent low-flow channel. Similarly, the presence of LWD will be evaluated for the opportunity to leave such material in place. Key determinants include whether the LWD is deflecting flow toward banks and the proximity to a channel crossing or other facility. While the habitat benefits of LWD are sought in the Program Area, these benefits will be evaluated in balance of the potential flooding or erosion effects, or threats to infrastructure downstream due to the presence of LWD. Invasive vegetation such as blackberry or fast-growing multi-trunked species such as arroyo willow will be targeted for removal. Section 6.5 below describes vegetation management approaches in more detail.

Creation of Two-Stage Low-Flow Channel

Developing a low-flow channel that can successfully transport sediment under lower flow conditions (annual flows and smaller) is an important strategy to reduce sediment deposition. This approach is not only advantageous in terms of preserving channel capacity, but also provides important water quality, habitat, and fish migration benefits. The general approach is to design a smaller conveyance channel nested inside the overall channel width (Figure 6-5). This smaller nested channel will have the hydraulic geometry conditions adequate to convey and pass sediments under lower flow conditions. As described above, where a defined channel is absent, gradients are gentle, and flows are shallow and diffuse across the channel bed, on-going deposition will occur (Figure 5-3).

To the extent possible, excavation of a low-flow channel should follow the channel thalweg (low point or bottom) or the location of the existing (or pre-existing) low-flow channel. If the low-flow channel has been fully aggraded, a new channel will be designed and excavated to an appropriate width, depth, and slope for the reach. Sediment removal and low-flow channel excavation activities will not exceed the depth of the original channel design. To the extent possible, the low-flow channel form and alignment will be based on channel forms and sinuosity in the existing channel or of natural streams observed in the project area..

If the reach easement and channel cross section is too narrow for a sinuous low-flow alignment, the low-flow channel will be sited to the side of the channel easement that receives the most shade. In east-west aligned channels, this would be on the south side of the channel where the low-flow channel would receive the most shade from any vegetation present on the south bank. If the channel does not have much existing vegetation, either on the south or north sides, tree planting will be integrated with the project during the following planting season, as with all channels receiving maintenance that have planting opportunities (see Section 6.5 and Chapter 8, Section 8.5) for additional detail on SCWA's tree planting program).

Figure 6-1 provides an example cross section and plan view for the 2007 sediment removal and low-flow channel excavation project at Hinebaugh Creek. Figure 6-2f shows a sinuously carved low-flow channel excavated at East Washington Creek in 2007. At East Washington Creek, the sinuous low-flow channel was constructed and aligned to preserve existing trees that can provide shade and bank stability. Figure 5-3 illustrates the recently implemented 2008 sediment removal and two-stage low-flow channel development at Copeland Creek.

Dewatering

Dewatering of the stream may be required in order to conduct sediment removal in the channel. Many Program Area creeks are intermittent or ephemeral and are dry in the summer maintenance season. Other creeks are perennial and carry flow year-round. Several of the channels in urbanized areas, or downstream of urbanized areas that were historically dry in summer, now receive flows from urban runoff and contain water year-round.

If the channel is conveying water or ponding at the time of maintenance, dewatering techniques will be used. After several years experience, SCWA has developed a flexible dewatering approach for use in Program Area channels. Typically a coffer dam, pump, and re-routing pipeline are used together to dewater a short section of channel at a time. The coffer dams are typically constructed using sand or gravel bags or if conditions require, an inflatable rubber cofferdam. Pumping rates are set to match inflows to the coffer dam with the downstream release of the diverted flows. Pump intake lines are protected with screens according to NMFS and CDFG criteria to prevent the entrainment of aquatic species. The diverted flows are released back into the channel as near as possible to the downstream end of the project area. Silt bags are used at the end of the diversion pipe to reduce any sediment discharge downstream and to dissipate flow velocity and prevent scour at the discharge site. Figure 6-6 illustrates the typical dewatering method in plan and profile view. Figure 6-7 provides an example of dewatering from a recent project at Hinebaugh Creek.

If needed, the coffer dam, pump, re-routing pipeline method can be sequenced to dewater a longer reach of channel. Up to three coffer dams may be operated at a time (45 CY of sandbags and gravel), using a phased approach that allows one section to be dewatered while another section is being excavated. If used in sequence, the upstream dam and the middle dam are used to surround either end of the active project site (i.e., where sediment removal is occurring) and the middle dam and the downstream dam form the stilling basin which receives water pumped around the site and/or from inside the active project area. Pumped water is held in the stilling basin to reduce turbidity and is slowly released through the downstream coffer dam which is constructed of sandbags surrounding a central pipe equipped with a filter sock. The coffer dam(s) and pump system(s) are moved downstream along the project area as needed during sediment removal. Following project completion, the dewatering system is removed.

Channels will only be dewatered to the extent necessary to conduct sediment removal activities while protecting water quality and avoiding impacts to aquatic species. Specific BMPs for channel dewatering are described in Table 7-1, *Biological Resources Protection*.

6.3.3 Localized Sediment Removal

Localized sediment removal activities are much smaller in size than reach scale projects and typically occur at specific sites that experience sediment deposition or blockages. Most often localized sediment removal activities occur at culverted stream crossings where sediments tend to collect and deposit. Sediments often collect inside culvert crossings and also immediately upstream or downstream of the crossings (Figure 6-3). Due to the number of culverted stream crossings in the Program Area, removal of sediment from these locations is one of SCWA's most common sediment management activities. Table 6-1 summarizes localized sediment removal activities for the 2006-2008 maintenance seasons and represents the need for this work during a typical maintenance year.

The principal objective of this maintenance activity is to ensure adequate flood conveyance by removing accumulated sediment and debris from inside culverts. Culverted crossings often accumulate sediment and debris either due to their design conditions (size and slope) or due to debris or vegetation obstructions which cause secondary sedimentation. Several examples of blocked or partially occluded culverts are described and shown in the channel discussion in Chapter 4. Though typically occurring at culvert crossings, localized sediment removal activities can also occur at bridges, other facilities, or even at specific focus points at a mid-reach location.

Localized sediment removal projects will typically involve the following activities:

- removal of accumulated sediment from box culverts or corrugated metal pipes (CMP) and areas immediately upstream and downstream of the culverts or crossings (typically 100-200 linear feet and 75-200 cubic yards of sediment removal per crossing);
- installation of temporary access ramps if needed to enter the culvert crossings;
- dewatering if/as necessary; and
- selective removal or thinning of vegetation at sediment removal locations.

Most of the culvert crossings that SCWA maintains are concrete box culverts. Culverts greater than 36 inches in diameter tend to require use of an excavator from the road crossing above or directly inside the culvert if space allows. Large box culverts with cement bottoms and enough space for a person to enter may be cleared with a small Bobcat®, skid-steer, or walk-behind power-shovel as shown in Figure 6-3. A vacuum truck is also used to remove sediment from culverts.

Sediment removal from culvert crossings will also often include the removal of sediment and the clearing of debris both immediately upstream and downstream of the culvert. As described above, a designated in-channel sediment removal area immediately upstream or downstream of the culvert provides maintenance and environmental benefits. This is particularly advantageous at crossings because access from a roadway above is available. Using such in-channel targeted collection areas near crossings can reduce the need for additional in-channel disturbance further upstream or downstream of the crossing.

In addition to the concrete box culverts there are also many smaller culverts (12 to 36 inches) made of CMP. These culverts are generally private culverts that drain from adjacent properties. SCWA is not responsible for maintaining such local drainage culverts beyond SCWA's property or maintenance easement, but SCWA does maintain the outlet of such culverts when they enter flood control channels under their maintenance. A culvert outlet blocked with sediment or vegetation will not drain properly. Removing sediment from a small culvert outlet may require similar techniques as described above for culvert crossings, but may also simply require digging out the culvert outlet by hand.

The access, staging, vegetation thinning and clearing, and dewatering methods described above for reach scale sediment removal activities are also used for the localized sediment removal activities. The key distinction is the scale and extent of the activities. Whereas reach scale projects are typically greater than 1,500 linear feet, localized sediment removal projects are typically 100-200 feet long. Access, vegetation thinning, and dewatering activities all scale down accordingly for the localized sediment removal activities.

6.3.4 Intermediate Scale Sediment Removal Activities

Intermediate scale sediment removal activities involve activities that are smaller than reach scale projects but are larger than localized projects. These projects are generally 500-750 feet long and can occur at crossings or mid-reach locations where sediment has accumulated. Intermediate scale projects don't require sediment removal throughout the entire reach length; the exact length of work will depend on the specific reach conditions.

Intermediate scale sediment removal activities are often related to specific geomorphic features along the channel. For example, sediment may be collecting as a point-bar along the inside bend of a channel or may be collecting as a mid-channel longitudinal bar. Such features may be up to a few hundred feet long in distance. Sediment management approaches for such features may involve bar grading or geomorphic shaping activities that are more site-specific than the full reach scale sediment removal approach described above.

These approaches are used where in-channel bar or depositional features may provide good habitat or other environmental benefits. The SMP approach is to preserve such features in their locations, but to grade or shape their height to provide conveyance capacity as needed. Bar grading removes accumulated sediment from the top of the bar but does not alter the overall shape or dimension of the bar, thus maintaining the low-flow channel and flow sinuosity around the bar. Bar grading activities may require some degree of vegetation removal or thinning from the bar surface to allow for equipment access. Vegetation that is considered important in providing channel stability or anchoring the bar in place will be retained. In certain reaches, mid-channel bars may be very developed and solidified with mature willows that further anchor the bar in place. In such cases, mature trees that are healthy and of a desirable species (e.g., red willow [*Salix laevigata*], alder [*Alnus* ssp.]) will be removed with the root wad intact, appropriately pruned, and transplanted to a nearby appropriate location. The remainder of the bar will then be graded using techniques described above.

Table 7-1. Stream Maintenance Program Best Management Practices

BMP ID	Name	BMP
General Impact Avoidance and Minimization		
GEN-1	Work Window	1. All ground-disturbing maintenance activities occurring in the channel (i.e., from top-of-bank to top-of-bank) will take place during the low-flow period, between June 15 and October 31. Exceptions may be made for emergencies or on a project-by-project basis with advance approval of RWQCB, CDFG, NMFS, and/or USFWS as appropriate. 2. Once the first significant rainfall occurs, all in-channel equipment and/or diversion structures shall be removed. Exposed soils in upland areas will be stabilized via hydroseeding or with erosion control fabric/blankets. Significant rainfall is defined as 0.5 inch of rain in a 24-hour period. 3. Work on the upper banks of stream channels (e.g., vegetation, road, and v-ditch maintenance) may be conducted year round. Ground disturbing activities will only be conducted during periods of dry weather.
GEN-2	Staging and Stockpiling of Materials	1. Staging will occur on access roads, surface streets, or other disturbed areas that are already compacted and only support ruderal vegetation to the extent feasible. Similarly, to the extent practical, all maintenance equipment and materials (e.g., road rock and project spoil) will be contained within the existing service roads, paved roads, or other pre-determined staging areas. Staging areas for equipment, personnel, vehicle parking, and material storage shall be sited as far as possible from major roadways. 2. All maintenance-related items including equipment, stockpiled material, temporary erosion control treatments, and trash, will be removed within 72 hours of project completion. All residual soils and/or materials will be cleared from the project site. 3. As necessary, to prevent sediment-laden water from being released back into the channel during transport of spoils to disposal locations, truck beds will be lined with an impervious material (e.g., plastic), or the tailgate blocked with wattles, hay bales, or other appropriate filtration material. If appropriate, trucks may drain excess water by slightly tilting the loads and allowing the water to drain out through the applied filter. 4. Building materials and other maintenance-related materials, including chemicals and sediment, will not be stockpiled or stored where they could spill into water

Table 7-1. Cont.

BMP ID	Name	BMP
		bodies or storm drains or where they will cover aquatic or riparian vegetation. 5. No runoff from the project or staging areas, including from stockpiled spoils, may be allowed to enter the creek channel or storm drains without being subjected to filtration (e.g., vegetated buffer, hay wattles or bales, silt screens). 6. During dry season, no stockpiled soils shall remain exposed and unworked for more than 30 days. During wet season, no stockpiled soils shall remain exposed, unless surrounded by properly installed and maintained silt fencing or other means of erosion control. 7. All spoils will be disposed of in an approved location. Selection of the disposal location will be determined after the spoils have been tested for hazardous chemicals (see BMP HAZ-8).
GEN-3	Channel Access	1. Access points to the channel for the purposes of stream maintenance will be minimized according to need. Access points should avoid large mature trees, native vegetation, or other significant habitat features as possible. Temporary access points shall be sited and constructed to minimize tree removal. 2. In considering channel access routes, slopes of greater than 20 percent shall be avoided if possible. Any sloped access points will be examined for evidence of instability and either revegetated or filled with compacted soil, seeded, and stabilized with erosion control fabric as necessary to prevent future erosion. 3. Personnel will use the appropriate equipment for the job that minimizes disturbance to and compaction of the stream bottom. Appropriately-tired vehicles, either tracked or wheeled, will be used depending on the site and maintenance activity.
Air Quality Protection		
AQ-1	Dust Management (based on Bay Area Air Quality Management District's basic dust control measures for all sites)	1. Water all active maintenance areas as necessary to reduce dust emissions. In dry areas, this may be twice daily or more, while in already wet areas, no watering may be needed. 2. Cover all trucks hauling soil, sand, and other loose materials or require all trucks to maintain freeboard as necessary to prevent transported material from blowing from the trucks. 3. Sweep as necessary (with water sweepers or dry sweepers, as appropriate) all

Table 7-1. Cont.

BMP ID	Name	BMP
		paved access roads, parking areas and staging areas at construction sites. 4. Sweep streets as necessary (with water sweepers or dry sweepers, as appropriate) if visible soil material is carried onto adjacent public streets.
AQ-2	Enhanced Dust Management (based on Bay Area Air Quality Management District's enhanced dust control measures for sites greater than 4 acres)	1. As necessary, enclose, cover, water, or apply (non-toxic) soil binders to exposed stockpiles. 2. Limit traffic speeds on unpaved roads to 15 mph. 3. Install sandbags or other erosion control measures to prevent silt runoff to public roadways.
Biological Resources Protection		
General Measures		
BR-1	Area of Disturbance	1. Activities will avoid damage to or loss of native vegetation to the maximum extent feasible. 2. Soil disturbance shall not exceed the minimum area necessary to complete the operations as described.
BR-2	Pre-Maintenance Educational Training	1. At the beginning of each maintenance season and before conducting stream maintenance activities, all personnel will participate in an educational training session conducted by a qualified biologist.[1] This training will include instruction on how to identify bird nests, recognize special-status species that may occur in the work areas, and the appropriate protocol if any nests or listed species are found during project implementation. 2. Personnel who miss the first training session or are hired later in the season must participate in a make-up session before conducting maintenance activities.
BR-3	Biotechnical Bank Stabilization	If hydraulic conditions allow, the natural bank will be retained or a biotechnical repair technique will be used rather than, or along with, a hardscape repair.
BR-4	Impact Avoidance and	1. All dewatering activities conducted in streams bearing state- or federally-listed

[1] A qualified biologist (including those specializing in botany, wildlife, and fisheries) is determined by a combination of academic training and professional experience in biological sciences and related resource management activities. SCWA may also utilize appropriately experienced and/or trained environmental staff. Resumes will be submitted to CDFG, USFWS and/or NFMS for approval prior to commencement of biological surveys, as stated in CDFG, USFWS and NMFS permit conditions.

Table 7-1. Cont.

BMP ID	Name	BMP
	Minimization During Dewatering	salmonids shall comply with the terms and conditions of the Russian River Biological Opinion (summarized in BMP BR-18), and any other Biological Opinions and associated Consistency Determinations issued by NOAA or DFG for the SMP. 2. Prior to dewatering, the best means to bypass flow through the work area will be determined to minimize disturbance to the channel and avoid direct mortality of fish and other aquatic vertebrates. The area to be dewatered will encompass the minimum area necessary to perform the maintenance activity. The period of dewatering will extend for the minimum amount of time needed to perform the maintenance activity. Where feasible and appropriate, dewatering will occur via gravity driven systems. Where feasible and appropriate, diversion structures shall be installed on concrete sections of the channels, such as concrete box culverts often used at road crossings. 3. A species relocation plan (BMP BR-5) shall be implemented as a reasonable best effort to ensure that native fish and other native aquatic vertebrates and macroinvertebrates are not stranded. 4. Instream cofferdams shall only be built from materials such as sandbags, clean gravel, or rubber bladders which will cause little or no siltation or turbidity. Visqueen shall be placed over sandbags to minimize water seepage into the maintenance areas. The visqueen shall be firmly anchored to the streambed to minimize water seepage. If necessary, the footing of the dam shall be keyed into the channel bed at an appropriate depth to capture the majority of subsurface flow needed to dewater the streambed. 5. When use of gravity fed dewatering is not feasible and pumping is necessary to dewater a work site, a temporary siltation basin and/or use of silt bags may be required to prevent sediment from re-entering the wetted channel. 6. Downstream flows adequate to prevent fish or vertebrate stranding will be maintained at all times during dewatering activities. Bypass pipe diameter will be sized to accommodate, at a minimum, twice the summer baseflow. 7. Diverted and stored water will be protected from maintenance activity-related pollutants, such as soils or equipment lubricants or fuels. 8. If necessary, discharged water will pass over some form of energy dissipater to keep erosion of the downstream channel to a minimum. Silt bags will be equipped

Table 7-1. Cont. Page 5 of 31

BMP ID	Name	BMP
		to the end of discharge hoses and pipes to remove sediment from discharged water. 9. For full channel dewatering, filtration devices or settling basins will be provided as necessary to ensure that the turbidity of discharged water is not visibly more turbid than in the channel upstream of the maintenance site. If increases in turbidity are observed, additional measures shall be implemented such as a larger settling basin or additional filtration. If increases in turbidity persist, turbidity measurements will be taken on a regular (i.e., at least daily) basis up- and downstream of the cofferdam enclosure. Data recorded will be compared against Regional Water Quality Control Board Basin Plan water quality standards. If Basin Plan standards are being exceeded, additional measures shall be installed and monitored to ensure Basin Plan standards are met. 10. When maintenance is completed, the flow diversion structure shall be removed as soon as possible. Impounded water will be released at a reduced velocity to minimize erosion, turbidity, or harm to fish or amphibians downstream. Cofferdams will be removed so surface elevations of water impounded above the cofferdam will not be reduced at a rate greater than one inch per hour. 11. The area disturbed by flow bypass mechanisms will be restored at the completion of the project. This may include, but is not limited to, recontouring the area and planting of riparian vegetation as appropriate.
BR-5	Fish and Amphibian Species Relocation Plan	1. All fish relocation conducted in streams bearing state- or federally-listed salmonids shall comply with the terms and conditions of the Russian River Biological Opinion (summarized in BMP BR-18), and any other Biological Opinions and associated Consistency Determinations issued by NOAA or DFG for the SMP. This measure will also apply to relocation of other special status species aquatic species (i.e., foothill yellow-legged frog and western pond turtle), and native aquatic species that could be relocated. Relocation for California red-legged frog will be conducted in accordance with BMPs BR-10 and BR-11 and any additional measures contained in the forthcoming SMP Biological Opinion issued by the USFWS. 2. Prior to and during dewatering activities, native fish, tadpoles, and other vertebrates will be excluded from the work area by blocking the stream channel above and below the work area with fine-meshed net or screens. The bottom of the screens will be completely secured to the channel bed. Exclusion screening

Table 7-1. Cont.

BMP ID	Name	BMP
		will be placed in areas of low water velocity to minimize fish impingement. Screens will be checked periodically and cleaned of debris to permit free flow of water. 3. The most efficient means for capturing fish will be determined and implemented. Complex stream habitat generally requires the use of electrofishing equipment, whereas in deep pools, fish may be concentrated by pumping-down the pool and then removing the fish by seining or dipnetting. Ample time will be scheduled to allow for a reasonable fish removal effort to be conducted. 4. Initial fish relocation efforts will be conducted several days prior to the start of maintenance activities. This provides the biologist an opportunity to return to the work area and perform additional electrofishing passes immediately prior to maintenance activities. 5. All native captured fish will be allowed to recover from electrofishing before being returned to the stream. 6. During dewatering, a qualified biologist will direct and monitor activities as necessary to net and rescue any additional fish and/or amphibians that may have become stranded throughout the dewatering process. 7. Prior to capturing fish and/or amphibians, the most appropriate release location(s) will be identified and used. The following issues will be considered when selecting release site(s): ▪ proximity to the project area; ▪ similar water temperature as capture location; ▪ ample habitat availability prior to release of captured fish; ▪ presence of other same species so that relocation of new individuals will not upset the existing prey/predation function; ▪ low potential for relocated individual to transport disease; and ▪ low likelihood of fish reentering work site or becoming impinged on exclusion net or screen. 8. In areas where aquatic vertebrates are abundant, to increase survival rates and ensure captured vertebrates are not held overly long, capture will be periodically

Table 7-1. Cont.

BMP ID	Name	BMP
		ceased, and release will occur at predetermined locations.
BR-6	On-Call Wildlife Biologist	A qualified biologist will be on-call in southern Sonoma County and available to visit a project site at any point during maintenance activities in the event a special status species is encountered.
Species-Related Measures		
BR-7	Special Status Plants	1. For projects located in areas where federally-listed plant species have been identified as potentially occurring (see SMP Manual Table 7-3), a qualified botanist will conduct appropriately timed focused botanical surveys of the project site for these species. If these species is observed in or near the project site, SCWA will follow the measures below as well as any additional measures contained in the forthcoming Biological Opinion issued by the USFWS for the SMP. 2. For projects located in areas where special status plant populations have been identified as potentially occurring (see SMP Manual Table 7-3), a qualified botanist will conduct appropriately timed focused botanical surveys of the project site for special status plant occurrences. A qualified botanist will also assess habitat suitability for the potential occurrence of special status plant species at any newly identified sediment disposal sites or previously unidentified staging areas. 3. If discovered, special-status plant populations identified during the field surveys and with potential to be impacted will be enumerated, photographed and conspicuously flagged to maximize avoidance, as well as to determine the total number of individuals affected. If feasible, the project shall be redesigned or modified to avoid direct and indirect impacts on special-status plant species. 4. Special-status plant species near the project site will be protected from temporary disturbance by installing environmentally sensitive area fencing (orange construction barrier fencing) around special-status plant species populations. Protective fencing will be installed under the direction of the botanist as necessary to protect the plant and its habitat; where feasible, the environmentally sensitive area fencing will be installed at least 50 ft. from the edge of the population. Where special-status plant populations are located in wetlands, silt fencing will also be installed. The location of the fencing will be shown on the maintenance design drawings and marked in the field with stakes and flagging. The design specifications will contain clear language that prohibits maintenance-related activities, vehicle operation, material and equipment storage, and other surface-

Table 7-1. Cont.

BMP ID	Name	BMP
		disturbing activities within the fenced environmentally sensitive area. 5. Vegetation management activities in sensitive plant areas will be conducted under the guidance of the botanist. These activities should be timed following the blooming periods of potentially occurring listed species, after the month of June. 6. If impacts to state or federally listed plants are unavoidable, then the Agency shall coordinate with the appropriate resource agencies and local experts to determine whether transplantation of special-status plant species is feasible. If the agencies concur that it is a feasible mitigation measure, the botanist shall develop and implement a transplantation plan in coordination with the appropriate agencies. As part of the plan, the Agency, in conjunction with a qualified restoration ecologist and DFG and/or USFWS, shall identify a suitable on- or off-site location for mitigation and appropriate methods for seed collection, propagation, relocation, maintenance and monitoring. If the impacted species are annuals, it is expected that the current seed crop from the individuals to be lost will be collected (as well as immediate soils making up the dormant seed bed) and then sown on appropriate habitat located on the mitigation site. If the species is a perennial, it is expected that both the seed and the plants themselves will be salvaged and relocated to the mitigation site. Seed from the populations that will be impacted may be collected and propagated at a native plant nursery, prior to planting to increase the potential for establishment and survival. Annual monitoring of the mitigation site shall be conducted for 5 years to assess vegetative density, population size, natural recruitment, and plant health and vigor. Monitoring results may trigger management actions such as collection and sowing of additional seed, tillage/disturbance within existing populations to induce establishment, installation of container plants, and control of exotic invasive vegetation such as yellow star thistle to ensure successful plant establishment and survival. The site shall be evaluated at the end of the 5-year monitoring period to determine whether the mitigation has met the success criteria identified in the rare plant relocation, management, and protection plan. 7. If appropriately timed focused botanical surveys cannot be conducted in areas identified as suitable for listed plants prior to vegetation management activities, then the Agency shall assume presence of the plant species in question and coordinate with the appropriate resource agencies and local experts to develop appropriate mitigation for the impact.
BR-8	Nesting Migratory Bird and Raptor	1. To the extent feasible, maintenance activities, including tree trimming, will take

Table 7-1. Cont.

BMP ID	Name	BMP
	Pre-maintenance Surveys	place outside the migratory bird and raptor nesting period (February 15 through August 15 for most birds). During the nesting bird season, work sites that are less densely vegetated will be prioritized, to facilitate pre-maintenance surveys and decrease the likelihood of disturbing undiscovered nests. 2. If maintenance activities must be scheduled to occur during the nesting season, a qualified wildlife biologist, familiar with the species and habitats in the Program Area, will be retained to conduct pre-maintenance surveys for raptors and nesting birds within suitable nesting habitat within 300 feet of SMP activities. The surveys should be conducted within one week before initiation of maintenance activities within those habitats. If no active nests are detected during surveys, activities may proceed. Vegetation removal activities will be conducted under the guidance of a biologist. If active nests are detected then measure 3 would be implemented. 3. If active nests are identified within the SMP area, non-disturbance buffers shall be established at a distance sufficient to minimize disturbance based on the nest location, topography, cover and species' tolerance to disturbance. Buffer size shall be determined in cooperation with the CDFG. If active nests are found within 300 feet of the project area, a qualified biologist shall be on site as necessary to monitor the nests for signs of nest disturbance. If it is determined that maintenance activity is resulting in nest disturbance, work shall cease immediately and CDFG shall be contacted. Buffers will be developed through consultation with CDFG. Buffers will remain in place until biologists determine that the young have successfully fledged or nests have been otherwise abandoned.
BR-9	California Freshwater Shrimp Avoidance and Impact Minimization for Vegetation Management	Maintenance activities occurring along streams supporting California freshwater shrimp will be restricted to only conducting vegetation management and/or debris removal above the water level. In addition, vegetation or debris overhanging into pools or glides (slow or slack water) within the natural reaches of Sonoma Creek will not be removed or altered. ***Note:*** *The only stream maintained under the SMP that supports California freshwater shrimp is Sonoma Creek. This creek has natural and modified channels along its length, and does not have any engineered channels. Therefore, the only type of activity that will be conducted along Sonoma Creek is vegetation management for hydraulic easement purposes. Applying this BMP will ensure that stream channels which support California freshwater shrimp will retain habitat elements (e.g., undercut banks with exposed, fine roots of willows or alders, trailing vines and overhanging woody vegetation) and continue to provide habitat for this species.*

Table 7-1. Cont.

BMP ID	Name	BMP
BR-10	California Red-legged Frog Avoidance and Impact Minimization Measures for Ground-Disturbing Activities	1. For ground-disturbing maintenance activities occurring in areas where California red-legged frog (CRLF) has been identified as potentially occurring (see SMP Manual Table 7-3), a qualified biologist will conduct pre-maintenance surveys to assess habitat within the proposed maintenance area. 2. If suitable breeding or foraging habitat is present then focused surveys using the USFWS CRLF survey protocol will be completed or CRLF presence will be assumed. The USFWS will be contacted and any site-specific recommendations will be implemented. 3. If CRLF are present or assumed present, a qualified biological monitor, or a biologist with an Incidental Take Permit, will inspect the area daily before the start of work and will be present during maintenance activities in sensitive habitats. If appropriate, SCWA will install exclusionary fencing. 4. In the event that a CRLF is encountered within the maintenance area, the USFWS Sacramento Field Office will be contacted within 48 hours of any CRLF observations, and a qualified biologist will move the frog to a safe location outside of the project area. Actions taken to move CRLF will be consistent with applicable USFWS and CDFG regulations and permits. The biological monitor will have the authority to stop work if a CRLF is encountered until such a time as the frog may be moved to an area outside of the project area fencing. 5. If dewatering of a creek is required, dipnet and seine surveys for CRLF tadpoles will be completed prior to initiation of dewatering. Captured tadpoles will be moved to a safe location elsewhere in the creek.
BR-11	California Red-legged Frog Avoidance and Impact Minimization Measures for Vegetation Management	1. For vegetation maintenance activities occurring in areas where CRLF frog has been identified as potentially occurring (see SMP Manual Table 7-3), a qualified biologist will conduct pre-maintenance surveys of aquatic habitats and identify potential CRLF breeding and foraging areas. These areas will be flagged and avoided by maintenance crews. 2. In areas where CRLF could potentially occur, field crews conducting hand trimming of vegetation will access channel banks by foot only and will avoid entering open water. Vehicles will be restricted to existing access roads. 3. In work sites where potential CRLF breeding and foraging areas were identified during the pre-maintenance survey, a qualified biological monitor or a biologist with an Incidental Take Permit, will be on-site during project activity in sensitive

Table 7-1. Cont.

BMP ID	Name	BMP
		habitats. The biological monitor will have the authority to stop work if a CRLF (or any of its life stages) is encountered until such a time as the frog may be moved to an area away from the project site. 4. The USFWS Sacramento Field Office will be contacted within 48 hours of any CRLF observations.
BR-12	California Tiger Salamander Avoidance and Impact Minimization Measures for Sediment and Debris Removal	1. For sediment and debris removal maintenance activities occurring in areas where California tiger salamander (CTS) has been identified as potentially occurring (see SMP Manual Table 7-3), a qualified biologist will conduct pre-maintenance surveys of upland habitats and identify areas with small mammal burrows. Areas with an abundance of small mammal burrows will be flagged and avoided by maintenance crews. 2. Maintenance activities will be restricted to the streambed and avoid disturbance to adjacent upland habitat. 3. Sediment and debris removal activities shall minimize removal of upland vegetation and soil compaction. 4. If upland banks must be traversed by heavy equipment to access a streambed, the route will be located where no small mammal burrows are present and will be delineated by temporary fencing to minimize upland habitat disturbance. 5. If burrows or other suitable aestivation habitat are present where sediment or debris removal activities are proposed, a qualified biological monitor or a biologist with an Incidental Take Permit will be on call during project activity in proximity to upland CTS habitat. The biological monitor will have the authority to stop work if a CTS is encountered until such a time as the animal is moved to an area away from the project site. 6. Maintenance activities located in proximity to upland CTS habitat will be scheduled to avoid the CTS migration season (October 15 – June 30). If work must be completed during the migration season, barrier fencing will be installed to exclude CTS from maintenance areas. 7. In the event that a California tiger salamander is encountered within the maintenance area, a biologist with an Incidental Take Permit, or biologist approved by the USFWS, will move the salamander to a safe location with suitable underground refugia (e.g., open burrow of appropriate depth) outside of the maintenance area. Actions taken to move CTS will be consistent with applicable

Table 7-1. Cont.

BMP ID	Name	BMP
		USFWS and CDFG regulations and permits. 8. The USFWS Sacramento Field Office will be contacted within 48 hours of any California tiger salamander observations.
BR-13	California Tiger Salamander Avoidance and Impact Minimization Measures for Bank Stabilization	1. For bank stabilization activities occurring in areas where California tiger salamander has been identified as potentially occurring (see SMP Manual Table 7-3), a qualified biologist will conduct pre-maintenance surveys of upland habitats and identify areas with burrows and/or other suitable aestivation habitat. 2. If burrows or other suitable aestivation habitat are present where bank stabilization activities are proposed, a qualified biological monitor or a biologist with an Incidental Take Permit, will be on call during project activity in proximity to upland CTS habitat. The biological monitor will have the authority to stop work if a CTS is encountered until such a time as the animal is moved to an area away from the project site. 3. Maintenance activities located in proximity to upland CTS habitat will be scheduled to avoid the CTS migration season (October 15 – June 30). If work must be completed during the migration season, barrier fencing will be installed to exclude CTS from maintenance areas. 4. In the event that a California tiger salamander is encountered within the maintenance area, a biologist with an Incidental Take permit, or biologist approved by the USFWS, will move the salamander to a safe location with suitable underground refugia (e.g., open burrow of appropriate depth) outside of the fenced maintenance area. Actions taken to move CTS will be consistent with applicable USFWS and CDFG regulations and permits. 5. The USFWS Sacramento Field Office will be contacted within 48 hours of any California tiger salamander observations.
BR-14	California Tiger Salamander Avoidance and Impact Minimization Measures for Vegetation Management	1. For vegetation management activities occurring in areas where California tiger salamander has been identified as potentially occurring (see SMP Manual Table 7-3), a qualified biologist will conduct pre-maintenance surveys of upland habitats and identify areas with small mammal burrows. Areas with an abundance of small mammal burrows will be flagged and avoided by maintenance crews. 2. Based on surveys, if California tiger salamander is identified as potentially present, then access across upland channel banks and adjacent upland habitats will be by

Table 7-1. Cont.

BMP ID	Name	BMP
		foot only. Vehicles will be restricted to existing access roads. 3. A qualified biological monitor, or biologist with an Incidental Take Permit, will be on call during project activity in proximity to upland CTS habitat. The biological monitor will have the authority to stop work if a CTS is encountered until such a time as the animal is moved to an area away from the project site. 4. In the event that a California tiger salamander is encountered within the maintenance area, a biologist with an Incidental Take Permit, or biologist approved by the USFWS, will move the salamander to a safe location with suitable underground refugia (e.g., open burrow of appropriate depth) outside of the fenced maintenance area. Actions taken to move CTS will be consistent with applicable USFWS and CDFG regulations and permits. 5. The USFWS Sacramento Field Office will be contacted within 48 hours of any California tiger salamander observations.
BR-15	Foothill Yellow-legged Frog Avoidance and Impact Minimization Measures for Ground-Disturbing Activities	1. For ground-disturbing activities occurring in areas where foothill yellow-legged frog has been identified as potentially occurring (see SMP Manual Table 7-3), a qualified biologist will conduct pre-maintenance surveys to assess habitat within the proposed maintenance area. 2. A qualified biologist will inspect the maintenance area daily before the start of work. If appropriate, SCWA will install exclusionary fencing. In the event that foothill yellow-legged frogs are encountered within the maintenance area, a qualified biologist will move the frog to a safe location outside of the maintenance area. Actions taken to move foothill yellow-legged frog will be consistent with applicable CDFG regulations and permits. 3. If dewatering a creek segment is required, a qualified biologist will conduct visual and dipnet surveys and move captured frogs and tadpoles to a safe location in the creek. Actions taken to move foothill yellow-legged frog will be consistent with applicable CDFG regulations and permits. 4. CDFG will be notified within 48 hours of any foothill yellow-legged frog observations.
BR-16	Foothill Yellow-legged Frog Avoidance and Impact Minimization Measures for	1. For vegetation maintenance activities occurring in areas where foothill yellow-legged frog has been identified as potentially occurring (see SMP Manual Table 7-3), a qualified biologist will conduct pre-maintenance surveys of aquatic habitats and identify potential foothill yellow-legged frog breeding and foraging areas.

Table 7-1. Cont.

BMP ID	Name	BMP
	Vegetation Management	These areas will be flagged and avoided by maintenance crews. 2. Based on surveys, if foothill yellow-legged frog is identified as potentially present, then field crews will access channel banks by foot only and will avoid entering open water. Vehicles will be restricted to existing access roads.
BR-17	Western Pond Turtle Pre-maintenance Surveys for Ground-Disturbing Activities	1. For projects located in areas where western pond turtle has been identified as potentially occurring (see SMP Manual Table 7-3), a qualified biologist will conduct pre-maintenance surveys to assess habitat within the proposed maintenance area. 2. If suitable instream habitat for the western pond turtle is present in the maintenance area, a qualified biologist will inspect the maintenance area daily before the start of work. In the event that a western pond turtle is encountered before or during the maintenance activity, a qualified biologist will move the turtle to a safe location outside of the work area. Actions taken to move western pond turtle will be consistent with applicable CDFG regulations and permits. 3. If dewatering of a creek segment is required, a qualified biologist will be present and will move turtles – if found – to a safe location in the creek. Actions taken to move western pond turtle will be consistent with applicable CDFG regulations and permits. 4. CDFG will be notified within 48 hours of any western pond turtle observations.
BR-18	Zone 1A Salmonid Avoidance and Impact Minimization Measures (based on NMFS Russian River BO issued on September 24, 2008)	These conditions apply to steelhead-bearing streams identified in the BO as: Laguna de Santa Rosa, Copeland Creek, Santa Rosa Creek, and Windsor Creek. SCWA will not perform any flood control maintenance activities in the Mark West Creek mainstem or tributaries of Mark West Creek upstream of the confluence with its largest tributary, the Laguna de Santa Rosa. As such, maintenance activities conducted on Wikiup or Fulton Creeks are not covered under the Zone 1A BO and will require a separate consultation with NMFS. Sediment maintenance activities conducted in steelhead-bearing streams will comply with the terms and conditions of Reasonable and Prudent Measure 5 of the Russian River BO for Zone 1A, which states: 1. **Term and Condition A:** SCWA shall isolate work areas located in aquatic habitat from the flowing stream and relocate listed salmonids prior to proceeding with in-channel work for food control maintenance or habitat enhancement:

Table 7-1. Cont.

BMP ID	Name	BMP
		▪ retain a qualified biologist with expertise in anadramous salmonid biology; ▪ the biologist shall be onsite during all dewatering events; ▪ all captured salmonids will be properly cared for; ▪ if any salmonids are found dead or injured, the Santa Rosa Area NMFS office will be contacted immediately; and ▪ NMFS staff or persons designated by NMFS will be allowed on-site during dewatering activities. 2. **Term and Condition B:** at all channel maintenance sites in Zone 1A, SCWA will: ▪ check construction equipment for leaks each day prior to conducting work in the channel; ▪ ensure that all fill material for cofferdams is fully contained; ▪ ensure that all diversion pumps are screened in compliance with NMFS' and CDFG's fish screening criteria; ▪ ensure that coffer dams are properly sized and maintained throughout the duration of maintenance activities; and ▪ ensure that all material is removed after completion of the project. 3. **Term and Condition C:** SCWA will provide NMFS and DFG with reports on construction-related and fish relocation activities by February 15 of the year following maintenance. 4. **Term and Condition D:** SCWA will reduce impacts on habitat complexity: ▪ all work in natural channels, except for revegetation activities, will be conducted between June 15 and October 15; ▪ no work will be started that cannot be completed before the onset of a storm event; ▪ vehicles may be driven in the dry streambed only as necessary to accomplish work; ▪ all exposed/disturbed areas on upper stream banks within the project site

Table 7-1. Cont.

BMP ID	Name	BMP
		will be stabilized; ▪ install erosion control measures to divert runoff to stable areas; ▪ all new riprap will be planted with willows or other native trees; ▪ no grouted riprap shall be installed; ▪ bioengineering techniques shall be incorporated into all bank stabilization projects; ▪ when grading gravel bars, a buffer of 25 feet or 10 percent of the maximum bar width, whichever is greater, shall be maintained; ▪ SCWA will construct a low flow channel at sediment removal sites in Zone 1A to provide enhanced migration habitat through sediment removal areas. 5. Sediment removal project designs will be submitted to NMFS and DFG 60 days prior to implementation for approval. 6. The low flow channel shall be monitored at least two times in-between large storm events during the winter period to assess its function as a migration corridor and impact on stream stability.
BR-19	Zone 2A and 3A Salmonid Avoidance and Minimization Measures	*[placeholder for forthcoming NMFS BO for Zone 2/3A. Until then, BR-18 will be utilized for salmonid-bearing streams.]*
Cultural Resources Protection		
CR-1	Cultural Resources Investigation	For maintenance activities which require excavation into native soils (e.g., bank stabilization, culvert replacement, etc.), and for all new sediment disposal sites, a cultural resources investigation shall be conducted prior to performing the maintenance activity. The cultural resources investigation shall include the following elements: **1. Background Research and Native American Consultation.** An updated records search shall be conducted at locations planned for maintenance that have not had a records search completed within the previous five years. Sediment disposal sites shall only require an initial records search. Investigations should begin with a review of the data acquired for this document to determine whether the proposed activity will occur within a previously-known culturally-sensitive area. An

BMP ID	Name	BMP
		addendum records search at the NWIC will also be necessary to determine if any cultural resources have been recorded since the creation of this document. The records search will identify resources within or near the project location and determine whether that location has been previously surveyed up to current standards. In conjunction with the background research, the appropriate Native American organization will be contacted to provide comments or concerns about a maintenance activity location. 2. **Pedestrian Survey.** If an adequate survey has not been completed for a project location within a ten-year period from the date of scheduled maintenance, a pedestrian survey is required. Sediment disposal sites shall only require an initial pedestrian survey. All areas of exposed ground should be closely inspected for the presence of cultural materials. Areas of dense vegetation should be inspected as closely as possible and any exposed channel banks should be carefully examined for the presence of buried cultural resources. Depending on the likelihood for encountering subsurface remains, based on an analysis of site distribution and geomorphology of the project location, a series of small, hand-auger borings may be excavated, with all sediments passed through 1/4-inch screen, to assure that no subsurface archaeological materials are present. The auger borings would also provide an initial assessment of the surface integrity of the landform (e.g., is a substantial amount of imported or redeposit fill material present?) and provide additional information about the potential for buried archaeological material. If the limited subsurface testing does not reveal buried cultural material, there will be less likelihood that unexpected discoveries will delay activities. If an archaeological deposit is encountered, a preliminary assessment of site boundaries should be made. Any archaeological material recovered in auger holes will be recorded, cataloged, and re-deposited. A map should be prepared depicting site boundaries in relation to the project area, and the site should be recorded on a standard archaeological site record (DPR 523 form). 3. **Documentation.** If findings are negative, these results will be presented in the SMP annual notification package. If findings are positive, a positive Archaeological Survey Report (ASR)/Historic Property Survey Report (HPSR) will be prepared that includes appropriate background research, site records, and recommendations for additional work. The report will include results of

Table 7-1. Cont.

BMP ID	Name	BMP
		background research, descriptions of field work, findings, appropriate maps and photos, and a record of Native American consultation. A cover letter will detail management recommendations, which could include archaeological and Native American monitoring, site avoidance, or test excavations to determine site significance. The report will be submitted to SCWA and the NWIC. **4. Management Requirements.** If a cultural resource is located within an area of maintenance activity the following steps shall be implemented. The following are examples of management requirements regarding the treatment of known or unknown cultural resources; other measures may be implemented instead, provided they are at least as protective of the cultural resource in question. ▪ **Archaeological and Native American Monitoring:** SCWA shall retain the services of a Native American monitor and a qualified archaeological consultant that has expertise in California prehistory to monitor ground-disturbing activities within 200 feet of known archaeological sites or in areas designated as having a high potential for encountering archaeological sites. If an intact archaeological deposit is encountered, all soil disturbing activities in the vicinity of the deposit should stop until the deposit is evaluated. The archaeological monitor shall immediately notify SCWA of the encountered archaeological deposit. The monitors shall, after making a reasonable effort to assess the identity, integrity, and significance of the encountered archaeological deposit, present the findings of this assessment to SCWA. During the course of the monitoring, the archaeologist may adjust the frequency—from continuous to intermittent—of the monitoring based on the conditions and professional judgment regarding the potential to impact resources. ▪ **Cultural Resources Monitoring Plan:** If monitoring is the preferred recommendation, a cultural resources monitoring plan shall be prepared by a qualified professional archaeologist. The plan should address (but not be limited to) the following issues: - Training program for all construction involved in site disturbance and field workers; - Person(s) responsible for conducting monitoring activities, including Native American monitors; - How the monitoring shall be conducted and the required format and

Table 7-1. Cont.

BMP ID	Name	BMP
		content of monitoring reports, including any necessary archaeological re-survey; - Person(s) responsible for overseeing and directing the monitors; - Schedule for submittal of monitoring reports and person(s) responsible for review and approval of monitoring reports; - Procedures and construction methods to avoid sensitive cultural resource areas; - Clear delineation and fencing of sensitive cultural resource areas requiring monitoring; - Physical monitoring boundaries (e.g., 200-foot radius of a known site); - Protocol for notifications and stop-work guidelines in case of encountering of cultural resources, as well as methods of dealing with the encountered resources (e.g., collection, identification, curation); - Methods to ensure security of cultural resources sites; - Protocol for notifying local authorities (i.e. Sheriff, Police) should site looting and other illegal activities occur during construction. - If SCWA, in consultation with the monitors, determines that a significant archaeological resource is present and that the resource could be adversely affected by the proposed Project, SCWA shall: - Re-design the proposed project to avoid any adverse effect on the significant resource; or, - Implement an archaeological data recovery program (ADRP) (unless the archaeologist determines that the archaeological resource is of greater interpretive than research significance, and that interpretive use of the resource is feasible). The project archaeologist and SCWA shall meet and consult to determine the scope of the ADRP. The archaeologist will prepare a draft ADRP and submit it to SCWA for review and approval. The ADRP will identify how the proposed data recovery program will preserve the significant information the archaeological resource is expected to contain. The ADRP will identify the scientific/historic research questions applicable to the expected resource, the data classes

Table 7-1. Cont.

BMP ID	Name	BMP
		the resource is expected to possess, and how the expected data classes will address the applicable research questions. Data recovery, in general, shall be limited to the portions of the historic property that could be adversely affected by the proposed Project. Destructive data recovery methods shall not be applied to portions of the archaeological resources if nondestructive methods are practical.
CR-2	Previously Undiscovered Cultural Resources	**Inadvertent Discoveries:** If discovery is made of items of historical or archaeological interest, activity will immediately cease in the project location (within approximately 50-feet) of discovery. Prehistoric archaeological materials might include obsidian and chert flaked-stone tools (e.g., projectile points, knives, scrapers) or toolmaking debris; culturally darkened soil ("midden") containing heat-affected rocks, artifacts, or shellfish remains; and stone milling equipment (e.g., mortars, pestles, handstones, or milling slabs); and battered stone tools, such as hammerstones and pitted stones. Historic-period materials might include stone, concrete, or adobe footings and walls; filled wells or privies; and deposits of metal, glass, and/or ceramic refuse. After cessation of excavation the contractor shall immediately contact SCWA. Maintenance will not resume until authorization is received from the SCWA. ▪ In the event of unanticipated discovery of archaeological indicators during construction, SCWA will retain the services of a qualified professional archaeologist to evaluate the significance of the items prior to resuming any activities that could impact the site. ▪ In the case of an unanticipated archaeological discovery that is determined to be potentially eligible for listing in the National and/or California Register, and the site cannot be avoided, SCWA will implement an ADRP, prepared by a qualified archaeologist, as outlined under BMP CR-1. **Discovery of Human Remains:** If potential human remains are encountered, SCWA shall halt work in the vicinity of the find and contact the county coroner in accordance with Public Resources Code Section 5097.98 and Health and Safety Code Section 7050.5. If the coroner determines the remains are Native American, the coroner will contact the NAHC. As provided in Public Resources Code Section 5097.98, the NAHC will identify the person or persons believed to be most likely descended from the deceased Native American. The Most Likely Descendent makes recommendations for means of treating or disposing of, with appropriate dignity, the human remains and any associated grave goods as provided in Public Resources Code Section 5097.98.

BMP ID	Name	BMP
CR-3	Previously Undiscovered Paleontological Resources	If fossil remains are encountered during maintenance, the maintenance activity will be stopped until a qualified professional paleontologist can assess the nature and importance of the find and recommend appropriate treatment. SCWA shall retain a consultant who meets the Society for Vertebrate Paleontology's criteria for a "qualified professional paleontologist" (Society of Vertebrate Paleontology Conformable Impact Mitigation Guidelines Committee 1995). Treatment may include preparation and recovery of fossil materials so that they can be housed in an appropriate museum or university collection, and may also include preparation of a report for publication describing the finds. SCWA shall be responsible for ensuring that the recommendations of the paleontologist regarding treatment and reporting are implemented.
Hazardous Materials Safety		
HAZ-1	Spill Prevention and Response Plan	The Agency will develop a Spill Prevention and Response Plan prior to commencement of maintenance activities. The plan will summarize the measures required under BMPs HAZ-2 through HAZ-6. It will also require that: 1. Equipment and materials for cleanup of spills be available on site and that spills and leaks will be cleaned up immediately and disposed of properly; 2. Prior to entering the work site, all field personnel shall be appropriately trained in spill prevention, hazardous material control, and clean-up of accidental spills. 3. Field personnel shall implement measures to ensure that hazardous materials are properly handled and the quality of water resources is protected by all reasonable means. 4. Spill prevention kits shall always be in close proximity when using hazardous materials (e.g., crew trucks and other logical locations). All field personnel shall be advised of these locations and trained in their appropriate use. The Agency will routinely inspect the work site to verify that the Spill Prevention and Response Plan is properly implemented and maintained. The Agency will notify contractors immediately if there is a noncompliance issue and will require compliance. Absorbent materials will be used on small spills located on impervious surface rather than hosing down the spill; wash waters shall not discharge to the storm drainage system or surface waters. For small spills on pervious surfaces such as soils, wet materials will be excavated and properly disposed rather than burying it. The

Table 7-1. Cont.

BMP ID	Name	BMP
		absorbent materials will be collected and disposed of properly and promptly. As defined in 40 CFR 110, a federal reportable spill of petroleum products is the spilled quantity that: ▪ violates applicable water quality standards; ▪ causes a film or sheen on, or discoloration of, the water surface or adjoining shoreline; or ▪ causes a sludge or emulsion to be deposited beneath the surface of the water or adjoining shorelines. If a spill is reportable, the contractor's superintendent will notify the Agency, and the Agency will take action to contact the appropriate safety and cleanup crews to ensure that the Spill Prevention and Response Plan is followed. A written description of reportable releases must be submitted to the appropriate RWQCB and the California Department of Toxic Substances Control (DTSC). This submittal must contain a description of the release, including the type of material and an estimate of the amount spilled, the date of the release, an explanation of why the spill occurred, and a description of the steps taken to prevent and control future releases. The releases will be documented on a spill report form. If an appreciable spill has occurred, and results determine that project activities have adversely affected surface water or groundwater quality, a detailed analysis will be performed to the specifications of DTSC to identify the likely cause of contamination. This analysis will include recommendations for reducing or eliminating the source or mechanisms of contamination. Based on this analysis, the Agency or contractors will select and implement measures to control contamination, with a performance standard that surface and groundwater quality must be returned to baseline conditions. These measures will be subject to approval by the Agency, DTSC, and the RWQCB.
HAZ-2	Equipment and Vehicle Maintenance	1. All vehicles and equipment will be kept clean. Excessive build-up of oil or grease will be avoided. 2. All equipment used in the creek channel will be inspected for leaks each day prior to initiation of work. Action will be taken to prevent or repair leaks, if necessary. 3. Vehicle and equipment maintenance activities will be conducted off-site or in a designated, protected area away from the channel where vehicle fluids and spills

Table 7-1. Cont.

BMP ID	Name	BMP
		can be handled with reduced risk to water quality. 4. If maintenance must occur on-site, designated areas will not directly connect to the ground, surface waters, or the storm drainage system to prevent the run-on of stormwater and runoff of spills. The service area will be clearly designated with berms, sandbags, or other barriers. 5. Secondary containment, such as a drain pan or drop cloth, to catch spills or leaks will be used when removing or changing fluids. Fluids will be stored in appropriate containers with covers, and properly recycled or disposed of off-site. 6. Cracked batteries will be stored in a non-leaking secondary container and removed from the site. 7. Spill clean-up materials will be stockpiled where they are readily accessible. 8. Incoming vehicles and equipment will be checked for leaking oil and fluids (including delivery trucks, and employee and subcontractor vehicles). Leaking vehicles or equipment will not be allowed on-site.
HAZ-3	Equipment and Vehicle Cleaning	1. Equipment will be cleaned of any sediment or vegetation before transferring and using in a different watershed to avoid spreading pathogens or exotic/invasive species between watersheds. 2. Vehicles and equipment will not be washed on-site. Vehicle and equipment washing will occur on an appropriate wash rack at SCWA's maintenance center.
HAZ-4	Refueling	1. No fueling shall be done in the channel (top-of-bank to top-of-bank) unless equipment stationed in these locations cannot be readily relocated (e.g., pumps and generators). 2. All off-site fueling sites (e.g., on access roads above the top-of-bank) shall be equipped with secondary containment and avoid a direct connection to underlying soil, surface water, or the storm drainage system. 3. For stationary equipment that must be fueled on-site, secondary containment, such as a drain pan or drop cloth, shall be provided in such a manner to prevent accidental spill of fuels to underlying soil, surface water, or the storm drainage system.
HAZ-5	On-Site Hazardous Materials Management	1. The products used and/or expected to be used and the end products that are produced and/or expected to be produced after their use will be inventoried.

Table 7-1. Cont.

BMP ID	Name	BMP
		2. As appropriate, containers will be properly labeled with a "Hazardous Waste" label and hazardous waste will be properly recycled or disposed of off-site. 3. Contact of chemicals with precipitation will be minimized by storing chemicals in watertight containers or in a storage shed (completely enclosed), with appropriate secondary containment to prevent any spillage or leakage. 4. Quantities of equipment fuels and lubricants greater than 55 gallons shall be provided with secondary containment that is capable of containing 110% of the primary container(s). 5. Petroleum products, chemicals, cement, fuels, lubricants, and non-storm drainage water or water contaminated with the aforementioned materials shall not be allowed to enter receiving waters or the storm drainage system. 6. Sanitation facilities (e.g., portable toilets) will be surrounded by a berm, and a direct connection to the storm drainage system or receiving water will be avoided. 7. Sanitation facilities will be regularly cleaned and/or replaced, and inspected regularly for leaks and spills. 8. Waste disposal containers will be covered when they are not in use, and a direct connection to the storm drainage system or receiving water will be avoided. 9. All trash that is brought to a project site during maintenance activities (e.g., plastic water bottles, plastic lunch bags) will be removed from the site daily.
HAZ-6	Existing Hazardous Sites or Waste	Upon selection of maintenance project locations, the Agency will conduct a search for existing known contaminated sites on the State Water Resource Control Board's GeoTracker website (http://www.geotracker.waterboards.ca.gov). For any proposed maintenance sites located within 1,500 feet of any "open" sites where contamination has not been remediated, the Agency will contact the RWQCB case manager listed in the database. The Agency will work with the case manager to ensure maintenance activities would not affect cleanup or monitoring activities or threaten the public or environment. If hazardous materials, such as oil or paint cans, are encountered at the maintenance sites, the Agency will carefully remove and dispose of them according to the Spill Prevention and Response plan. Agency staff will wear proper protective gear and store the waste in an appropriate hazardous waste container until it can be disposed at a hazardous waste facility.

Table 7-1. Cont.

BMP ID	Name	BMP
HAZ-7	Fire Prevention	1. All earthmoving and portable equipment with internal combustion engines will be equipped with spark arrestors. 2. During the high fire danger period (April 1–December 1), work crews will have appropriate fire suppression equipment available at the work site. 3. On days when the fire danger is high and a burn permit is required (as issued by the relevant Air Pollution Control District), flammable materials, including flammable vegetation slash, will be kept at least 10 feet away from any equipment that could produce a spark, fire, or flame. 4. On days when the fire danger is high and a burn permit is required, portable tools powered by gasoline-fueled internal combustion engines will not be used within 25 feet of any flammable materials unless at least one round-point shovel or fire extinguisher is within immediate reach of the work crew (no more 25 feet away from the work area).
HAZ-8	Testing and Disposal of Spoils	As specified in the Sediment Sampling and Analysis Guidelines (SMP Manual Appendix B), after selecting potential sediment disposal locations and prior to disposing of excavated sediment, the Agency will test the sediment to determine the suitability for disposal based on presence of contaminants. Criteria for sediment disposal at the selected locations will dictate the concentrations of contaminants such as metals, pesticides, organic compounds, total organic carbon, asbestos, total sulfides, ammonia, and toxicity which are acceptable at the disposal locations. As specified in the Sediment Sampling and Analysis Guidelines, samples will be compared against federal and state environmental screening levels (ESLs) for protection of human health, groundwater quality, and terrestrial receptors. If hazardous levels of contaminants are present such that disposal at the preferred locations is not feasible, the material will be taken to a permitted hazardous waste facility.
Vegetation Management		
VEG-1	Removal of Existing Vegetation	1. Vegetation pruning and removal activities will be conducted under the guidance of a staff biologist or certified arborist. For tree relocation activities, a botanist, certified arborist, or other vegetation specialist will be on site to help direct maintenance activities and to consult if questions and/or issues arise. 2. Only vegetation that is noxious, invasive, hazardous, or could obstruct channel

Table 7-1. Cont.

BMP ID	Name	BMP
		flows will be removed. Herbaceous layers that provide erosion protection and habitat value will be left in place. Invasive plant species that inhibit the health and/or growth of native riparian trees will be targeted for removal. 3. Where a choice between species that may be removed to maintain flood conveyance is feasible, slower-growing species such as oaks (*Quercus* spp.) that develop large canopies will be preferentially preserved, because these species take longer to establish, and provide essential nesting habitat for cavity nesters and food sources for a variety of resident and migratory animals and birds. Faster-growing species such as alders (*Alnus* spp.) and cottonwoods (*Populus* spp.) are the second priority for preservation; these single-trunked species offer the benefit of improved flood conveyance and reduced roughness by comparison with multi-trunked species. 4. Vegetation will be removed and/or pruned in such a manner that channel roughness is reduced while allowing the maximum amount of vegetation to remain in place. Trees will be trimmed or pruned to reduce impedance of floodflows while allowing the canopy to develop. Specifics for each site will differ, but typical options include limbing up to remove lower branches that have potential to interfere with floodflows, and pruning into a "fan" roughly parallel to flow direction. In areas where extensive vegetation removal is desirable to maintain flood flow capacity, *phasing of remov*al shall be considered so that some vegetation may remain in place to provide habitat to birds. 5. Vegetation management will emphasize the preservation of large mature trees that provide well developed overstory for bird habitat, canopy closure for stream shading, and add vertical complexity to the riparian corridor. Vegetation management will be conducted in such a manner that maximizes shading over the active channel. Larger trees will be retained on both sides of north-south flowing streams and on the south side of east-west flowing streams. Where vegetation is removed from the active channel, removal will target nonnative species and removal of native species that are stiff and/or multi-trunked such as arroyo willow (*Salix lasiolepis*). Trees will never be topped as this encourages shrubby growth and weak branch attachments 6. Large woody debris, stumps, or root wads that are fully or partially buried and do not present a flood hazard shall be allowed to remain in place to provide habitat and to maintain bank stability.

Table 7-1. Cont.

BMP ID	Name	BMP
		7. If vegetation requires removal for access to project site, non-native species and/or quick growing species shall be targeted first for removal. Removal of native, mature trees will be avoided whenever possible. 8. To the extent feasible, removed native vegetation shall be saved to replant after maintenance or plant in other nearby sites. This includes the reuse of mulch and willow sprigs where possible.
VEG-2	Use of Herbicides	1. All herbicide use shall be consistent with all Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) label instructions and any use conditions issued by the Sonoma County Agricultural Commissioner. 2. Herbicide use will be restricted to the minimum amount needed to ensure adequate control of vegetation. 3. Application of herbicides to upland areas shall not be made within 72 hours of predicted rainfall. 4. Herbicides will not be directly applied to waters of the U.S., such as for ludwigia eradication. 5. Herbicides, including AquaMaster© and Renovate©, will not be used within 60 feet of areas identified in the Court-Ordered Stipulated Injunction for the protection of California red-legged frogs. This includes areas in Zones 1A and 3A, as well as Zones 8A and 9A (see SMP Manual Figure 3-29 for detail on where these areas are located.) The Agency will review the details and exceptions in the court order and comply with the herbicide use buffers as appropriate. 6. As required by the Court-Ordered Stipulated Injunction for pesticide use near Pacific salmon-supporting waters in Sonoma County, pesticides specified in the injunction including triclopyr (Renovate©) will not be used within 20 yards of salmon-supporting waters. The Agency will review the details and exceptions in the court order and comply with the herbicide use buffers as appropriate.
VEG-3	Planting and Revegetation After Soil Disturbance	1. Sites where maintenance activities result in exposed soil will be stabilized to prevent erosion and revegetated with native vegetation as soon as feasible after maintenance activities are complete. 2. Revegetation will occur at a ratio of at least 1½: 1 to account for initial mortality of plantings.

Table 7-1. Cont.

BMP ID	Name	BMP
		3. If soil moisture is deficient, new vegetation will be supplied with supplemental water until vegetation is firmly established. 4. To the extent possible, native grass seed will be used when seeding a project site. 5. Erosion control fabric, hydromulch, or other mechanism will be applied as appropriate to provide protection to seeds, hold them in place, and help retain moisture. 6. Revegetation shall be regularly monitored for survival for at five years or until minimum survival/cover is achieved. If invasive species colonize the area, action shall be taken to control their spread; options include hand and mechanical removal and replanting with native species.
Water Quality and Channel Protection		
WQ-1	Apply Erosion Control Fabric to or Hydroseeding of Exposed Soils	1. Upland soils exposed due to maintenance activities will be seeded and stabilized using erosion control fabric or hydroseeding. The channel bed and other areas below ordinary high water mark are exempt from this BMP. 2. Erosion control fabric will consist of natural fibers that will biodegrade over time. No plastic or other non-porous material will be used as part of a permanent erosion control approach. Plastic sheeting may be used to temporarily protect a slope from runoff, but only if there are no indications that special-status species would not be impacted by the application. 3. The site will be properly prepared to make sure the fabric/mat has complete contact with the soil. Sites can be prepared by grading and shaping the installation area; removing all rocks, dirt clods, vegetation, etc.; preparing the seedbed by loosening the top 2- to 3-inches of soil; and applying soil amendments as directed by soil tests, the seeding plan, and manufacturer's recommendations. 4. The area will be seeded before installing the fabric. All areas disturbed during installation will be re-seeded. 5. Erosion control fabric will be anchored in place. Anchors can include U-shaped wire staples, metal geotextiles stake pins or triangular wooden stakes. 6. The manufacturer's installation recommendations will be followed. 7. Other erosion control measures shall be implemented as necessary to ensure that sediment or other contaminants do not reach surface water bodies for stockpiled

Table 7-1. Cont.

BMP ID	Name	BMP
		or reused/disposed sediments.
WQ-2	Prevent Scour Downstream of Sediment Removal	After sediment removal, the channel shall be graded so that the transition between the existing channel both upstream and downstream is smooth and continuous between the maintained and non-maintained areas and does not present a "wall" of sediment or other blockage that could erode once flows are restored to the channel.
WQ-3	In-Channel Grading	1. Where pre-maintenance channel form exhibited desirable features, the channel bed will be regraded to mimic the channel form before work was conducted. 2. Where possible, grading may include channel enhancements such as excavation of a low-flow channel, development of a meander, or riffle/pool configurations. No channel grading will occur below the as-built design for the flood control channels. 3. If gravels that have the potential to be utilized for spawning are removed to conduct maintenance activities, the gravels will be carefully removed and stored where maintenance activities will not impact the quality of the gravel. The gravel shall be replaced as close to original conditions as possible upon completion of the maintenance activities. 4. Where in-stream gravel and gravel (or cobble) bars are encountered, sediment removal activities will aim to preserve the overall shape and form of the existing bar or gravel feature. Sediment removal activities will aim to retain the form of the gravel or cobble bar feature, while reducing bar elevations as necessary to accommodate flood conveyance capacity.
Good Neighbor Policies		
GN-1	Work Site Housekeeping	1. SCWA will maintain the work site in a neat and orderly condition, and will leave the site in a neat, clean, and orderly condition when work is complete. To the extent feasible, slash, sawdust, cuttings, etc. will be removed to clear the site of vegetation debris. Paved access roads will be swept and cleared of any residual vegetation or dirt resulting from the maintenance activity. 2. For activities that last more than one day, materials or equipment left on the site overnight will be stored as inconspicuously as possible, and will be neatly arranged.
GN-2	Public Outreach	1. In efforts to keep the public informed about stream maintenance work, why it is necessary, when it occurs, and what a neighborhood can expect when crews arrive to conduct maintenance work, SCWA will post and update information about the

Table 7-1. Cont.

BMP ID	Name	BMP
		SMP and maintenance activities on their website (http://www.scwa.ca.gov/about_your_water/). 2. Each spring, once maintenance sites have been selected for the annual work season, a newspaper notice will be published with information on the maintenance sites, approximate work dates, and contact information. This information will also be posted on SCWA's website. 3. For high profile projects, at SCWA's discretion, signs will be posted in the neighborhood to notify the public at least one week in advance of maintenance schedules, trail closures, and road/land closures as necessary and as possible. Signage used at work sites will provide contact information for lodging comments and/or complaints regarding the activities.
GN-3	Noise Control	1. With the exception of emergencies, normal work will be limited to normal business hours (8:00 a.m.–5:00 p.m.). Routine activities in residential areas will not occur on Saturdays, Sundays, or SCWA observed state holidays except during emergencies, or with approval by the local jurisdiction and advance notification of surrounding residents. 2. SCWA will ensure that power equipment (vehicles, heavy equipment, and hand equipment such as chainsaws) is equipped with original manufacturer's sound-control devices, or alternate sound control that is no less effective than those provided as original equipment. Equipment will be operated and maintained to meet applicable standards for construction noise generation. No equipment will be operated with an unmuffled exhaust.
GN-4	Traffic Flow, Pedestrians, and Safety Measures	1. To the extent feasible, work will be staged and conducted in a manner that maintains two-way traffic flow on public roadways in the vicinity of the work site. If temporary lane closures are necessary, they will be scheduled outside of peak traffic hours (7:00-10:00 a.m. and 3:00-6:00 p.m.) to the maximum extent practicable, and advance warning signage, a detour route, and flaggers will be provided in both directions. 2. When work is conducted on public roads and may have the potential to affect traffic flow, work will be coordinated with local emergency service providers as necessary to ensure that emergency vehicle access and response is not impeded. 3. Public transit access and routes shall be maintained to the extent feasible. If public transit would be affected by temporary road closures and require detours, affected

Table 7-1. Cont.

BMP ID	Name	BMP
		transit authorities will be consulted and kept informed of project activities. 4. Heavy equipment and haul traffic will be prohibited in residential areas, except when no other route to and from the site is available. 5. Roadway segments or intersections in the vicinity of project sites will be assessed to determine if they are at, or approaching an LOS that exceeds local standards. Maintenance traffic will avoid these locations to the extent feasible, either by traveling different routes or by traveling at non-peak times of day. 6. Adequate off-street parking will be provided or designated public parking areas will be used for maintenance workers' personal vehicles and maintenance-related vehicles not in use through the maintenance period. 7. Access for driveways and private roads will be maintained to the extent feasible. If brief periods of maintenance would temporarily block access, property owners will be notified prior to maintenance activities.
GN-5	Odors	Sediment that is rich in decaying organic matter that could generate assorted malodorous gases such as reduced sulfur compounds shall be handled to minimize impacts on sensitive receptors such as nearby residents. In general, such materials will be hauled off of the site at the time of excavation. Where it needs to be temporarily stockpiled, maintenance personnel shall stockpile potentially odorous sediments as far as possible from residential areas or other odor sensitive land uses.

Table 7-2. Best Management Practices by Activity

				Vegetation Management									Other Activities							
BMP	**Name**	**Sediment Removal**	**Bank Stabilization**	Willow Removal	Blackberry Removal	Cattail Removal	Ludwigia Removal	Tree Pruning and Exotics Removal	Tree Removal and Relocation	Mowing	Nursery Stock Tree Planting	Herbicide Application	Modified and Natural Channel Maintenance	Access Road Maintenance	V-Ditch Maintenance	Culvert Repair and Installation	Debris Removal	Fence Maintenance	Graffiti Removal	Sediment Disposal
General Impact Avoidance and Minimization																				
GEN-1	Work Window	X	X	X		X	X	X	X	X		X	X			X	X			X
GEN-2	Staging and Stockpiling of Materials	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
GEN-3	Channel Access	X	X	X	X	X	X	X	X	X	X	X	X			X	X			
Air Quality Protection																				
AQ-1	Dust Management	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X
AQ-2	Enhanced Dust Management	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X
Biological Resources Protection																				
BR-1	Area of Disturbance	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
BR-2	Pre-maintenance Educational Training	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
BR-3	Biotechnical Bank Stabilization		X										X		X	X				
BR-4	Impact Avoidance and Minimization During Dewatering	X	X				X						X		X	X				
BR-5	Fish and Amphibian Species Relocation Plan	X	X				X						X		X	X				
BR-6	On-Call Wildlife Biologist	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
BR-7	Special Status Plant Survey	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
BR-8	Nesting Migratory Bird and Raptor Pre-maintenance Surveys	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Table 7-2. Cont.

				Vegetation Management									Other Activities							
BMP	**Name**	**Sediment Removal**	**Bank Stabilization**	Willow Removal	Blackberry Removal	Cattail Removal	Ludwigia Removal	Tree Pruning and Exotics Removal	Tree Removal and Relocation	Mowing	Nursery Stock Tree Planting	Herbicide Application	Modified and Natural Channel Maintenance	Access Road Maintenance	V-Ditch Maintenance	Culvert Repair and Installation	Debris Removal	Fence Maintenance	Graffiti Removal	Sediment Disposal
BR-9	California Freshwater Shrimp Avoidance and Impact Minimization for Vegetation Management	X	X	X	X	X	X	X	X			X	X			X	X			X
BR-10	California Red-legged Frog Avoidance and Impact Minimization Measures for Ground-Disturbing Activities	X	X	X	X	X	X	X	X		X		X	X	X	X	X			
BR-11	California Red-legged Frog Avoidance and Impact Minimization Measures for Vegetation Management			X	X	X	X	X	X	X	X	X	X							
BR-12	California Tiger Salamander Avoidance and Impact Minimization Measures for Sediment and Debris Removal	X		X		X	X						X	X	X	X	X			X
BR-13	California Tiger Salamander Avoidance and Impact Minimization Measures for Bank Stabilization		X													X				
BR-14	California Tiger Salamander Avoidance and Impact Minimization Measures for Vegetation Management			X	X			X	X	X	X	X	X	X	X		X	X	X	
BR-15	Foothill Yellow-legged Frog Avoidance and Impact Minimization Measures for Ground-Disturbing Activities	X	X	X	X	X	X						X			X	X			

Table 7-2. Cont.

				Vegetation Management									Other Activities							
BMP	**Name**	**Sediment Removal**	**Bank Stabilization**	Willow Removal	Blackberry Removal	Cattail Removal	Ludwigia Removal	Tree Pruning and Exotics Removal	Tree Removal and Relocation	Mowing	Nursery Stock Tree Planting	Herbicide Application	Modified and Natural Channel Maintenance	Access Road Maintenance	V-Ditch Maintenance	Culvert Repair and Installation	Debris Removal	Fence Maintenance	Graffiti Removal	Sediment Disposal
BR-16	Foothill Yellow-legged Frog Avoidance and Impact Minimization Measures for Vegetation Management			X	X	X	X						X							
BR-17	Western Pond Turtle Pre-maintenance Surveys for Ground-Disturbing Activities	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
BR-18	Zone 1A Salmonid Avoidance and Impact Minimization Measures	X	X	X	X	X	X	X	X			X	X			X	X			
BR-19	Zones 2A and 3A Salmonid Avoidance and Impact Minimization Measures	X	X	X	X	X	X	X	X			X	X			X	X			
Cultural Resources Protection																				
CR-1	Phase I Cultural Investigation and Report		X						X				X	X	X	X				X
CR-2	Previously Undiscovered Cultural Resources	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
CR-3	Previously Undiscovered Palentological Resources	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X
Hazardous Materials Safety																				
HAZ-1	Spill Prevention and Response	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
HAZ-2	Equipment and Vehicle Maintenance	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Table 7-2. Cont. Page 4 of 5

				Vegetation Management									Other Activities							
BMP	**Name**	**Sediment Removal**	**Bank Stabilization**	Willow Removal	Blackberry Removal	Cattail Removal	Ludwigia Removal	Tree Pruning and Exotics Removal	Tree Removal and Relocation	Mowing	Nursery Stock Tree Planting	Herbicide Application	Modified and Natural Channel Maintenance	Access Road Maintenance	V-Ditch Maintenance	Culvert Repair and Installation	Debris Removal	Fence Maintenance	Graffiti Removal	Sediment Disposal
HAZ-3	Equipment and Vehicle Cleaning	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
HAZ-4	Refueling	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
HAZ-5	On-Site Hazardous Materials Management	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
HAZ-6	Existing Hazardous Sites or Waste	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
HAZ-7	Fire Prevention	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
HAZ-8	Testing and Disposal of Spoils	X	X										X	X	X	X	X			X
Vegetation Management																				
VEG-1	Removal of Existing Vegetation	X	X	X				X	X		X	X	X	X	X	X				
VEG-2	Use of Herbicides			X	X	X	X	X	X			X	X	X	X			X		
VEG-3	Planting and Revegetation After Soil Disturbance	X	X					X	X		X		X		X	X				
Water Quality and Channel Protection																				
WQ-1	Apply Erosion Control Fabric to or Hydroseeding of Exposed Soils	X	X	X	X	X		X	X				X	X	X	X	X	X		X
WQ-2	Prevent Scour Downstream of Sediment Removal	X											X							
WQ-3	In-Channel Grading	X	X										X			X				
Good Neighbor Policies																				
GN-1	Work Site Housekeeping	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Table 7-2. Cont.

				Vegetation Management									Other Activities							
BMP	**Name**	**Sediment Removal**	**Bank Stabilization**	Willow Removal	Blackberry Removal	Cattail Removal	Ludwigia Removal	Tree Pruning and Exotics Removal	Tree Removal and Relocation	Mowing	Nursery Stock Tree Planting	Herbicide Application	Modified and Natural Channel Maintenance	Access Road Maintenance	V-Ditch Maintenance	Culvert Repair and Installation	Debris Removal	Fence Maintenance	Graffiti Removal	Sediment Disposal
GN-2	Public Outreach	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
GN-3	Noise Control	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
GN-4	Traffic Flow, Pedestrians, and Safety Measures	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
GN-5	Odors	X	X										X		X	X	X	X		X

management needs of a flood control channel (e.g. small in stature, perennial, rhizomatous, and can survive being submerged for long periods) that receives urban runoff during the dry season. These species will be plugged (in appropriate groupings) on 5-10 foot centers in 20 percent of the area above the thalweg. Intermittent channels will be planted in a similar fashion but species selection will vary depending on the degree of saturation (e.g. wet meadow species would be used in these channels instead of emergent wetland species).

Species selected for in-channel use share a number of characteristics common to herbaceous (non-woody) wetland and transitional wetland species. These characteristics include the ability to tolerate long periods of total submergence, having a high capacity for vegetative reproduction, having a high fecundity (produces large quantities of seed), a rhizomatous growth habit, and a relatively diminutive stature. Rapid vegetative growth and the production of large quantities of seed are an important adaptation of instream and streamside plant species, especially for use in restoring aquatic habitat. These species can quickly re-establish after being buried under sediment by either propagating vegetatively, or via abundant seed production. The rhizomatous habit is important as these species spread via creeping underground stems which in high densities effectively knit the substrate together, help armor the toe and channel banks, and reduce (or eliminate depending on flows and location) the need to stabilize using rock.

Plant stature is an important consideration, and is related to how the plant is anticipated to behave during periods of higher flows. Herbaceous species tend to bend over in higher flows, allowing debris and sediment to pass over rather than being caught in unyielding stems. The lower the plant, the less debris and sediment it will catch. Figures 8-2 and 8-3 include a list of the species proposed to be used in SMP flood control channels for restoring aquatic habitat following sediment removal. The species in these figures are all native to Northern California (and more specifically Sonoma County); those used in the in-channel zone are generally less than three feet tall, and have all or most of the desired characteristics anticipated to perform well in the program's flood control channels.

Implementation and Monitoring

Plant material will be obtained from local sources preferentially as feasible. Figures 8-2 and 8-3 list the typical species planned to be established following sediment removal or bank stabilization activities. Trees will be in the five gallon size range. Shrubs will be one gallon size, and herbaceous species will be planted from seed or liners. Overbank and bank zones will also be seeded with native species with the composition and application rates specified in Table 8-4. The seed mixture will either be collected locally onsite or will be obtained from a seed supplier that can authenticate a regionally local source and augmented with additional native perennial grass seed collected locally.

Agency personnel will conduct plant installation or will oversee work done by watershed partners. Plants will be installed in the native soil and top dressed with a one-inch thick layer of certified weed-free fir bark mulch or other commercial planting mix. An irrigation basin one to two feet in diameter will be formed around each hole where feasible. Plants will be installed and mulched so that root crowns are at, or slightly above, the soil/mulch surface. Precise location of trees and shrub plantings in the upland and riparian zones will be determined in the field following completion of sediment removal activities. Planting will be conducted from late summer into early winter. Generally, the majority of planting is done in the fall and winter with the advent of the season's rains. However, toe plantings can be conducted any time of the year if the channel remains moist and flow velocities are amenable. Following maintenance activities, the project botanist will either position the plants themselves or place color-coded pinflags in specific planting locations for each shrub and tree species.

Holes will be prepared using hand tools or a mechanical auger. Over bank and side channel plantings will be installed with "dry water" following the manufactures recommendations to provide additional water reserves in the rooting zone. Additionally, overbank plantings and side channel plantings will be installed to have a "water basin" depression crafted out of the existing soil that will pool water slightly around the collar of the plant. These basins will then be mulched to reduce weed growth and retain moisture. Landscape fabric will be used for erosion control on slopes and disturbed areas.

Trees and shrubs will be irrigated manually during the dry season for three years. Irrigation frequency will be approximately weekly the first year, every two weeks the second year, and monthly during the third year.

Monitoring will be conducted at the project site for five years following construction and planting. Information collected will include the number and species planted at each site, square footage of channel planted, estimated percent canopy cover, number or percent of planted trees and shrubs surviving, and the annual cost for implementing the planting program Site conditions will be documented annually by taking repeat photographs at set reference locations. The monitoring data will be reviewed annually to evaluate the overall success of the revegetation approach.

Success criteria for shrubs and trees planted in overbank and side bank areas will be 75 percent survival. For the in-channel plantings, setting the appropriate criteria for survival is difficult due to lack of reference criteria and the dynamic environment of the channel bottom. Depending upon winter flow conditions, in-channel plantings could be covered in sediment or scoured and eroded by the following next year. Instead of establishing strict survival criteria for the in-channel zone, SCWA will monitor and document the presence of the planted species in the channel. Initial goals for the in-channel plantings will be some level of survival, retention, and successful colonization into the subsequent years. Based on plant monitoring, SCWA will adaptively develop appropriate future criteria for the SMP.

In the event of poor plant survival, corrective measures will include replanting to reach the 75 percent goal in the overbank and side bank areas. For the in-channel zone, selective replanting will be conducted along the low-flow channel to help stabilize it.

8.5.2 Invasive and Exotic Plant Removal Program

SCWA removes invasive and exotic plants as part of its on-site mitigation program. This beneficial activity occurs in tandem while general vegetation maintenance activities are occurring on–site, including vegetation thinning, pruning, and removal. Because the removal of invasive and exotic plants is closely integrated with the general vegetation management activities, it is described in the vegetation maintenance description of Chapter 6, Section 6.5.2.

Specific mitigation activities include the targeted removal of invasive and exotic species such as Himalayan blackberry (*Rubus armeniacus*) and tree of heaven (*Ailanthus altissima*). The removal of invasive and exotic species provides more room for desirable native species to establish. An increase in abundance of native vegetation over non-native vegetation improves overall riparian health. For example, native vegetation can provide more habitat opportunities to insects and birds that show preferential treatment for use of native plant species. Removing exotic species also helps prevent the monoculture common to areas dominated with exotics. When replaced with a diverse selection of native vegetation, the channels of the Program Area can support a more diverse set of species including insects, birds, small mammals, amphibians, and reptiles.

Monitoring of invasive and exotic plant removal will include tracking the number of invasive or exotic trees removed, length of channel of removal activities, area of removal activities for shrub or ground-cover species, observing whether recolonization of invasives occurs after removal, and documenting the annual cost for invasive and exotic removal.

8.5.3 Low-Flow Channel Design

For reach scale sediment removal projects, SCWA designs and implements a low-flow inset channel along the bed of the flood control channel. The low-flow channel provides on-site mitigation through multiple benefits. Because low-flow channels are implemented together with sediment removal activities, they are described above in Chapter 6, Section 6.3.2.

A key objective of a low-flow channel is to successfully transport sediment under lower flow conditions (annual flows and smaller). This is achieved through increased flow depth and velocity under low-flow conditions which are adequate to convey and pass sediments under the smaller flow conditions. This reduces sediment deposition, and ultimately reduces the need to conduct sediment removal activities. A sustainable low-flow channel also provides mitigating benefits of improving water quality, enhancing instream habitats, and preserving a migration corridor for fish.

The latter topic of enabling fish migration is particularly important in the program's steelhead-supporting streams such as Copeland Creek. Copeland Creek's engineered flood control channel is an important transport reach that leads steelhead to spawning areas in the upstream watershed and enhances smolt emigration. Reaches along Copeland Creek where low-flow channels have been developed maintain an open water unblocked corridor. In other reaches without a low-flow channel, the channel bed is typically blocked with deposited sediment and cattails which inhibits migration. Figure 5-3 provides photographs from Copeland Creek before and after sediment removal activities and shows the blocked channel condition prior to development of the low-flow channel.

The habitat and fish migration benefits of low-flow channels are described in the Russian River Watershed Biological Opinion (NMFS 2008). Additionally, the use of low-flow channels is a specifically mentioned term of the BO's Reasonable and Prudent Measures

(RPM). RPM 5 includes measures to reduce harm to listed salmonids resulting from activities along the Russian River, Dry Creek, and maintenance activities in Zone 1A of the SMP Area. Condition D of RPM 5 includes the requirement that "at sediment removal sites in Zone 1A, SCWA shall construct a low-flow channel to provide enhanced migration habitat through sediment removal areas" (NMFS 2008 p. 327). The BO also requires that low-flow channels be monitored at least two times between large storms during the winter period to assess their function as migration corridors and the possible effects of the low-flow channel on overall channel conditions. The SMP approach is consistent with the terms and conditions of the BO, and the SMP will comply with those terms. Similarly, the SMP considers the use of low-flow channels as an appropriate mitigation measure to be used with sediment removal projects of the SMP.

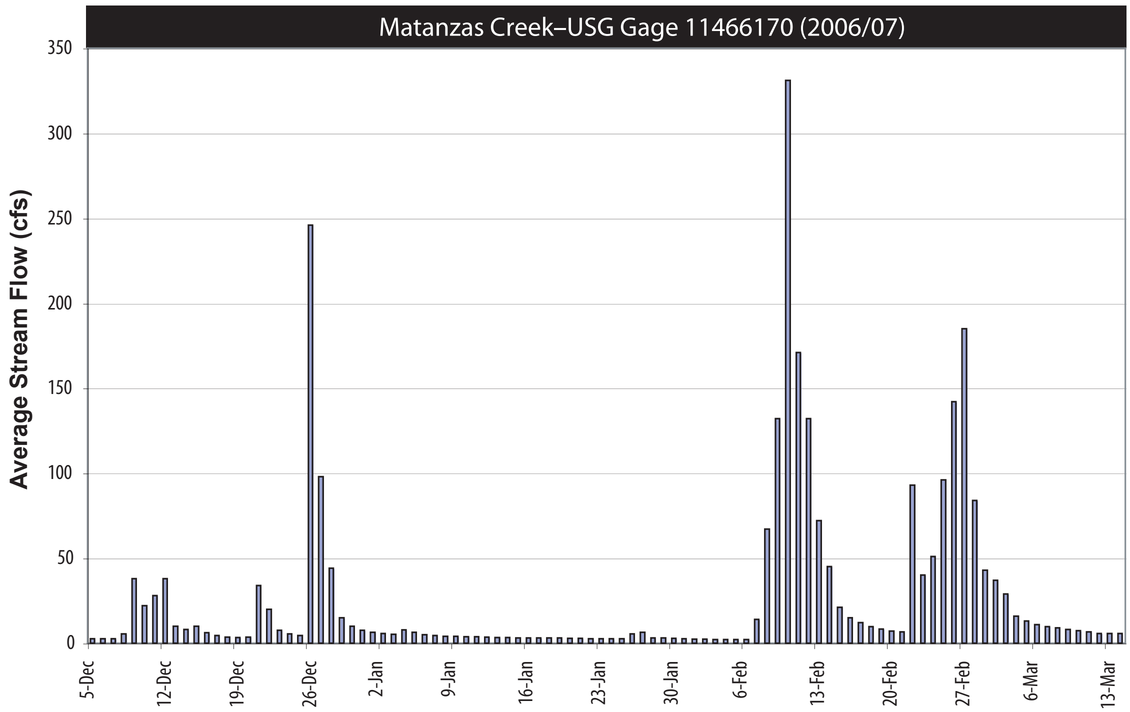
8.6 Off-Site Mitigation at Other SCWA Reaches (Tier 2)

Tier 2 mitigation provides in-kind mitigation at neighboring SMP reaches that afford an opportunity for mitigation. Tier 2 mitigation is very similar to Tier 1 on-site mitigation in that the focus is to provide reach-based in-kind habitat, stream function, or water quality benefits. The key difference is that the mitigation occurs at a SCWA reach which is not the subject of SMP maintenance activities during a given year. Tier 2 mitigation, and the Tier 3 mitigation described below, is implemented through a 10% matching contribution of SMP maintenance costs. Monitoring, reporting, and remedial actions (if necessary) will be combined with Tier 1 monitoring and reporting activities. As an example, an SMP reach like Bellevue-Wilfred Channel, Reach 1 (see Station A of Figure 5-1) provides many opportunities for habitat or functional improvement. In any given year such a channel may provide additional mitigation opportunities (Tier 2) beyond what SCWA would be doing on-site at other reaches (Tier 1). Tier 2 provides the mitigation program flexibility in finding other nearby stream channels to restore, in addition to the off-site watershed mitigation (Tier 3).

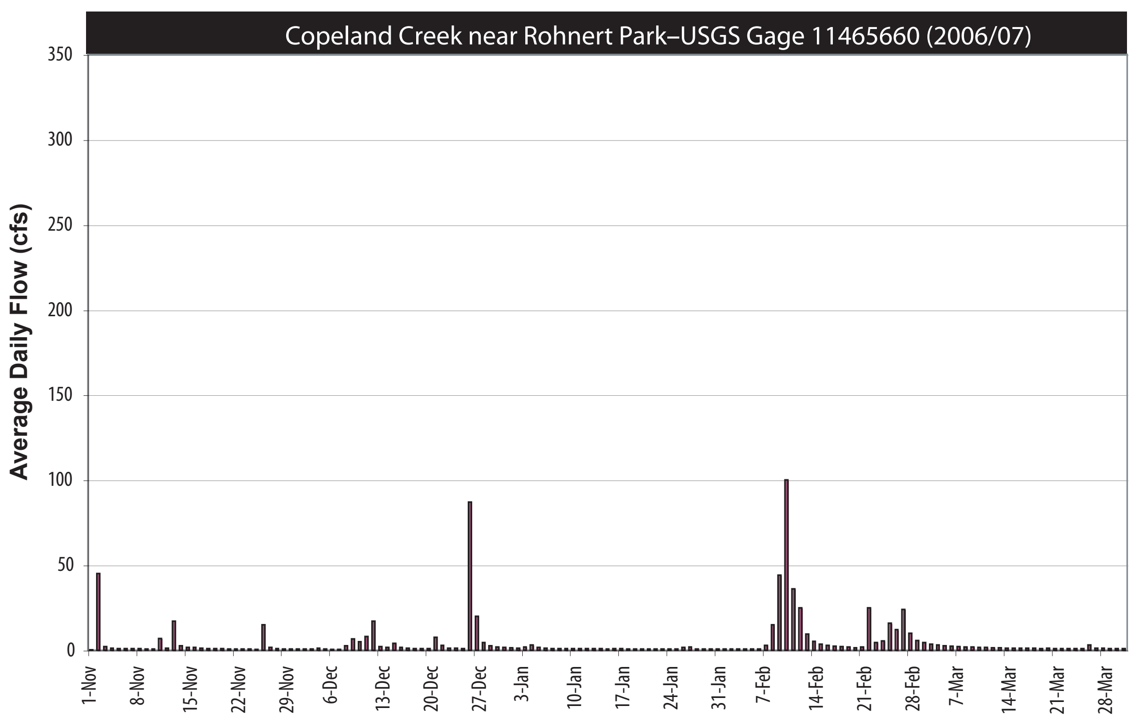
8.7 Integrated Watershed Mitigation (Tier 3)

8.7.1 Rationale and Purpose

Off-site watershed mitigation (Tier 3), in combination with Tier 1 and 2 mitigation actions, address residual impacts from SMP activities that are not adequately avoided or minimized prior to or during maintenance. As described above, off-site mitigation addresses the temporary loss of Beneficial Uses and ecological functions and values during the time gap between SMP maintenance activities and when Tier 1 mitigation occurs, and the time when Tier 1 mitigation has become fully functional and the temporary impacts have been eliminated. Off-site mitigation projects provide restorative and mitigating watershed solutions that address SMP impacts. Examples of off-site mitigation projects include native riparian plant revegetation, large woody debris installation, invasive plant removal, bioengineering/erosion control, and watershed-based sediment or other contaminant reduction actions.



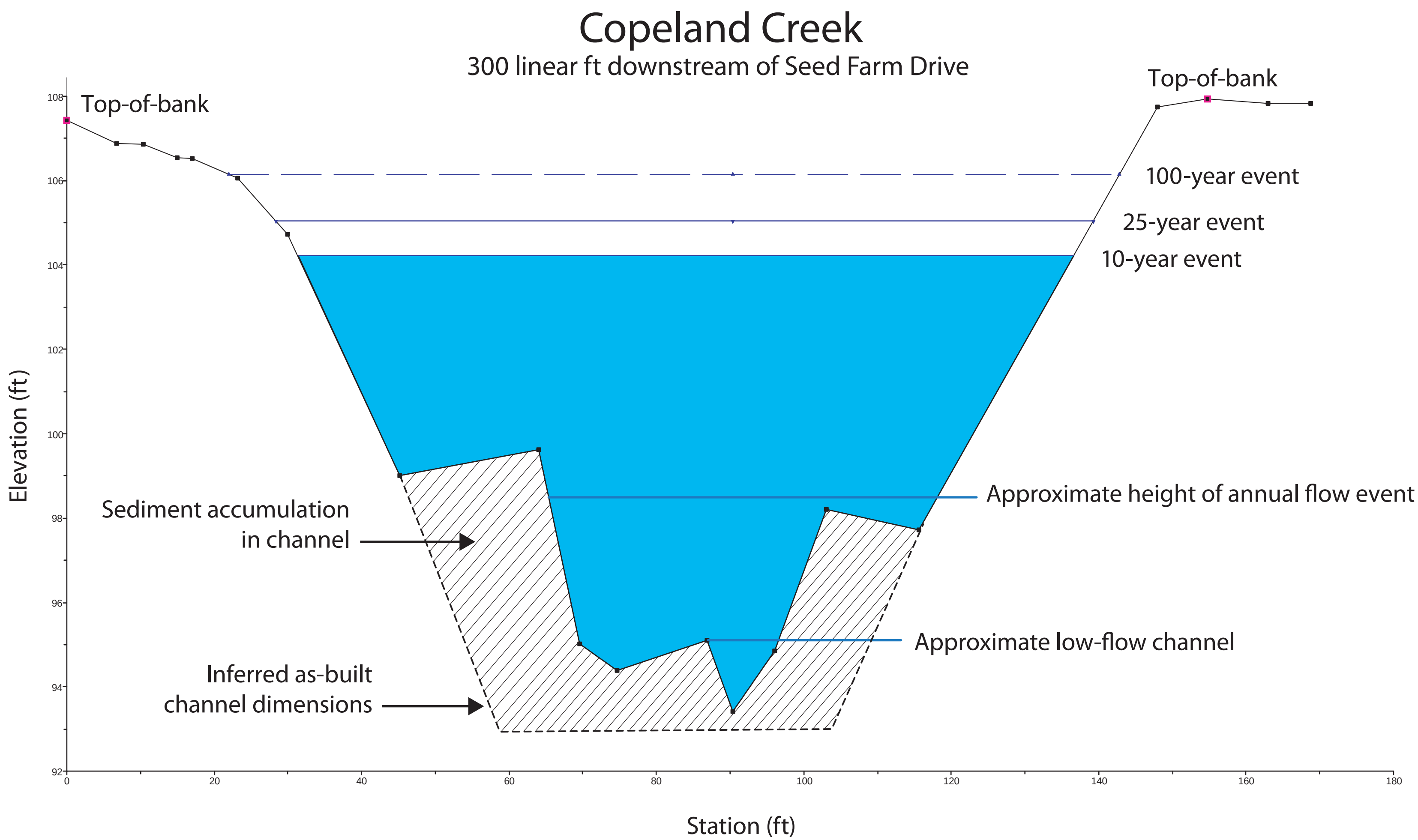
Source: United States Geological Survey 2007.



Source: United States Geological Survey 2007.

Horizon WATER and ENVIRONMENT

Figure 3-14
Average Daily Flows, Matanzas & Copeland Creeks, Winter Season 2006/2007



Horizon WATER and ENVIRONMENT

Figure 3-15
Typical Channel Cross Section with Estimated Water Surface Elevations

Copeland Creek – Reach 1

JURISDICTION: SCWA owned and maintained, located in Rohnert Park

LOCATION: Highway 101 to Laguna Channel confluence

ADJACENT LAND USE: Residential trailer park to north and commercial buildings to south

UPSTREAM: Copeland 2

LENGTH: 2,851 ft

CHANNEL EASEMENT CORRIDOR WIDTH: 105 ft

AVERAGE TOP-OF-BANK WIDTH: 54 ft

(b) Mid Reach 1 looking downstream channel beneath shade of willow in lower right (May 29, 2007).

MAINTENANCE HISTORY

(a) Reach 1 looking downstream from Redwood Dr; cattails grow in non-shaded channel portion just downstream of the Hwy 101 crossing (May 29, 2007).

PHYSICAL CONDITIONS

Reach setting: lowest Copeland Creek reach, between Hwy 101 and Upper Laguna, in lower alluvial plain, linear channel with increasing channel incision towards its lower end.

Active channel: linear throughout, 8-10 ft wide

Bed sediments/texture: in upper/mid reach small bars and sediment wedges forming at toe of bank comprised of sands/silts; small sand bars in channel in lower reach (photos c, d).

Bank structure: upper and mid reach has earthen banks 4-6 ft high (2:1 or 1.5:1); in the lower reach, the bank on south side heightens and steepens (photo c) as channel incises deeper beneath banks.

Water quality: debris and trash collect just downstream of Hwy 101 crossing.

Channel processes: upper and mid reach exhibits some mild deposition, including immediately downstream of the Hwy 101 crossing where cattails, sediment, and debris/trash can accumulate; in lower reach channel has downcut, most likely due to elevation/gradient adjustments towards the Laguna 3 confluence (photos c, d).

BIOLOGICAL CONDITIONS

Vegetation Composition: Canopy closure is 25-50%, increasing downstream as the channel narrows and deepens. At breaks in the canopy, cattails grow in isolated patches on bars.

Riparian Corridor: A band of willows (native Arroyo willows and non-native weeping willows) grows along the toe of the slope throughout most of reach. A fringe of emergent wetland vegetation is adjacent to willows, with rice cutgrass, watercress, and patches of cattails. A mixture of native and non-native trees are at top of bank and along access road, including coast live oak and Monterey pine. Upper banks support shrubby vegetation dominated by non-natives such as Himalayan blackberry and cotoneaster, with ruderal herbaceous vegetation dominated by Harding grass interspersed.

Instream Habitat: Reach includes some riffles/run sequences between shallow sand bars. Willows provides for additional habitat complexity through rootwads along lower banks. Willows also provide good shade of channel (photo b) in locations.

Listed species with potential to occur: known steelhead occurrence (reach is a migration corridor); potential habitat for western pond turtle.

(c) lower Reach 1 (near confluence with Laguna 3 and Washoe 1 reaches) looking upstream; note steep eroding bank on right and overall depth from top-of-bank; channel has incised in its lower zone to adjust for elevations at Laguna channel confluence (May 29, 2007).

(d) Lower Reach 1 (just upstream of Laguna 3 confluence) looking downstream (May 29, 2007).

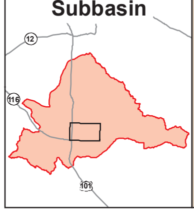
MANAGEMENT CONSIDERATIONS AND OPPORTUNITIES

Management considerations for the upper section of Copeland Creek Reach 1 focus on monitoring cattail growth downstream of the Hwy 101 crossing. This area downstream of the Hwy 101 crossing also collects debris and trash that will likely need periodic removal. In the mid reach area, willow vegetation provides nice canopy shading over channel, but will need to be monitored if willow growth in the channel becomes excessive. For now, the willow growth is mostly on the banks and does not require much maintenance. In the lower reach, bank erosion along the south banks near the Laguna 3 channel confluence should be monitored (photo c). If the bank erosion were to become worse and impact the access road, then bank stabilization/repair activities may be required.

Sonoma County Water Agency

Stream Maintenance Program

Upper Laguna Subbasin



Vegetation Type

- Blackberry Scrub
- Mixed Riparian Scrub
- Riparian Woodland (full canopy)
- Riparian Woodland (up to 75% canopy)
- Riparian Woodland (up to 25% canopy)
- Riparian Forest
- Ruderal
- Willow Scrub
- Developed
- SMP Maintenance Reaches

Sources:
Sonoma County Water Agency
County of Sonoma
AirPhotoUSA, 2005

FIGURE 4-40

Reaches and Vegetation

Upper Laguna (10 of 11)

0 500 1,000 1,500 2,000
Feet

1 inch equals 1,000 feet

Horizon WATER and ENVIRONMENT

Copeland Creek – Reach 5

JURISDICTION: City of Rohnert Park owner, SCWA maintenance easement

LOCATION: Rohnert Park, Snyder Ln Bridge to 1500 ft upstream

ADJACENT LAND USE: Residential to the north, recreational/school to the south

UPSTREAM: Copeland 6 (not actively managed); Past SCWA Copeland Creek Restoration Project above Petaluma Hill Road

LENGTH: 1,368 ft

CHANNEL EASEMENT CORRIDOR WIDTH: 77 ft

AVERAGE TOP-OF-BANK WIDTH: 89 ft

(b) Mid Reach 5 looking upstream; channel sinuosity increases with presence of "D-shaped" bar features adjacent to inner bend of channel (March 6, 2007).

MAINTENANCE HISTORY

(a) Reach 5 looking upstream; note pool-riffle sequence with cobble bar in foreground and distance (March 6, 2007).

PHYSICAL CONDITIONS

Reach setting: transitional reach between the steeper alluvial fan areas upstream to more gentle gradient alluvial plain setting below Snyder Lane.

Active channel: 8-10 ft wide in upper reach (photo a) increasing to approx 20 ft wide at Snyder crossing (photos b, c, d), average flow depth 6-12 in.

Bed sediments/texture: upper reach dominated by small cobbles (photo a), pebbles, coarse sands; sediments fine toward Snyder Bridge to medium/fine sands and silts.

Bank structure: earthen banks 2:1 to 1:1 (5-8 ft high) in upper reach, less steep and shallower banks in lower reach, no apparent bank stabilization issues.

Channel processes: riffle-pool sequences in upper reach (photo a), depositional bars adjacent to the bank increase toward lower reach (photos b, c), aggradation and widening of mid-channel bars upstream of Snyder Bridge (photo d).

BIOLOGICAL CONDITIONS

Vegetation Composition: mapping from 2006-2007 indicates 75% canopy closure for narrow 10-foot wide channel sections, 25-50% canopy closure for 20-ft wide sections.

Riparian Corridor: 20-30 ft wide on each bank; dominated by mature trees with dense blackberry understory (photo a); toe of slope supports dense stands of willow; bank shade, lack of fines, shallow depths result in limited emergent vegetation (photo c).

Instream Habitat: upper reach has low sinuosity, long shallow runs/glides, occasional riffles and pools; transition to lower reach has “D-shaped” cobble bars (photos b, c) at channel bends related to channel bends and mild sinuousity; further downstream more mid-channel bar aggradation occurs (photo d).

Listed species with potential to occur: Considered the best viable steelhead tributary in the Rohnert Park area. Known occurrence of steelhead, reach is migration corridor with known or potential rearing habitat; potential habitat for western pond turtle and foothill yellow-legged frog.

(c) Mid Reach 5 looking downstream, similar to (photo b) cobble bars run along inner channel bend, and mid channel riffle sequence (March 6, 2007).

(d) Reach 5 looking upstream from Snyder Lane crossing, multiple in channel bar features and fine sediments indicate increased depositional environment towards bridge (March 6, 2007).

MANAGEMENT CONSIDERATIONS AND OPPORTUNITIES

Due to general channel gradient, excessive deposition is not problematic through reach. Bars that are adjacent to bends in the channel in the mid-to-lower reach provide valuable bar-riffle-pool habitats. D-shaped bars reflect increased channel sinuosity in mid-reach, and do not appear to significantly reduce channel capacity. In lower Reach 5, 300 ft directly upstream of Snyder crossing, a more depositional environment emerges with larger and more prominent mid channel bar features (d), general deposition across the channel cross-section, and increased presence of fine sediments. Increased deposition is related to slope reduction and channel transition toward the Snyder Lane crossing.

The lower section of the reach near the Snyder crossing may need occasional sediment removal through its cross-section based on observed depositional bars. Key management opportunity at the lower reach is to maintain and mimic (where possible) the current sequence of elongate mid-channel bars, but simply skim the tops of the bars leaving the root of the bar in place. Keeping these channel forms and flow processes in place supports in-stream habitats. Additionally, removal of dense blackberry understory and limbing of dense willows in upper reach can maintain channel capacity and improve habitat.

Copeland Creek – Reach 4

JURISDICTION: City of Rohnert Park owner, SCWA maintenance easement

LOCATION: Snyder Lane to Country Club Dr

ADJACENT LAND USE: Primarily residential to north and south, community center to north by Snyder Ln

UPSTREAM: Copeland 5

LENGTH: 2,769 ft

CHANNEL EASEMENT CORRIDOR WIDTH: 136 ft

AVERAGE TOP-OF-BANK WIDTH: 86 ft

(b) Mid Reach 4 looking upstream from footbridge; multiple individual bars transitioning to sediment wedge across entire channel bed (March 6, 2007).

MAINTENANCE HISTORY

(a) Top of Reach 4 looking downstream from Snyder Ln; abundant deposition in multiple bars with finer sediments than Reach 5 (March 6, 2007).

PHYSICAL CONDITIONS

Reach setting: depositional reach, multiple mid-channel bars in upper reach transition to a continuous wedge of sediment that fills the entire channel bed width, overall channel width doubles in size from Reach 5 upstream, to about 40 ft.

Active channel: in upper reach, multiple low flow channels (~6 ft wide) pass around individual sediment bars, in lower reach, channel is diffuse, shallow (<6") and spread across in-channel sediment wedge (photos c, d).

Bed sediments/texture: upper reach dominated by sands and silts, large sediment wedge in lower reach shows fines at surface, but is likely coarser with sands/gravels below.

Bank structure: earthen banks 2:1 to 1:1 (4-6 ft high), no apparent bank stabilization issues

Channel processes: deposition and channel infilling occurs in multiple bars in the upper reach and more homogenous wedge in the lower reach, positive feedback cycle with cattails capturing fine sediments leading to the formation of bars/wedges.

BIOLOGICAL CONDITIONS

Vegetation Composition: depositional wedge supports dense cattails in approximately 90% of the channel, canopy closure generally 25% or less.

Riparian Corridor: confined to narrow band of willows (arroyo and weeping) growing along toe of bank slope.

Instream Habitat: some channel sinuosity around multiple bars of upper reach, with small pools to side of bars, gives way to homogeneous sediment wedge w/cattails in lower reach. Cattail density may provide good bird habitat but is poorer in-channel aquatic habitat.

Listed species with potential to occur: Considered the best viable steelhead tributary in the Rohnert Park area. Known occurrence of steelhead (reach is a migration corridor); potential habitat for western pond turtle.

(c) Mid Reach 4 looking downstream from foot bridge: similar to photo (b) sedimentation now occurs as broad wedge across entire channel bed, dense cattails on bars trapping more fine sediment (March 6, 2007).

(d) Bottom of Reach 4 looking upstream from Country Club Dr, similar to photo (c) wedge of sediment across entire channel bed, abundant vegetation trapping more fine sediment (March 6, 2007).

MANAGEMENT CONSIDERATIONS AND OPPORTUNITIES

The primary management issues in this reach are abundant sediment deposition and in-channel vegetation (cattails), which are collectively impairing the flow conveyance capacity and ecologic functioning of this reach. Sediment removal methods can increase flow conveyance while also improving in-channel habitat through creating a more defined and sinuous low-flow channel and bar sequence as appropriate for this reach. This reach has a thin riparian canopy with limited channel shading. Planting of more woody riparian species along the top of bank and along the toe of slope could both improve shading and inhibit cattail development. Additionally, the watershed projects upstream could identify and treat upstream sediment through erosion control and land-use treatments.

Copeland Creek – Reach 3

JURISDICTION: City of Rohnert Park owner, SCWA maintenance easement

LOCATION: Country Club Drive to Seed Farm Drive

ADJACENT LAND USE: Residential to north and south

UPSTREAM: Copeland 4

LENGTH: 926 ft

CHANNEL EASEMENT CORRIDOR WIDTH: 142 ft

AVERAGE TOP-OF-BANK WIDTH: 83 ft

(b) Mid Reach 3 looking downstream (March 6, 2007).

MAINTENANCE HISTORY

(a) Upper Reach 3 looking upstream to Country Club Dr. (March 6, 2007).

PHYSICAL CONDITIONS

Reach setting: short reach between road crossings, well defined low-flow channel with higher depositional benches to either side of the channel.

Active channel: single low flow channel (6-8 ft wide) excavated to 1-4 ft depth (photo a).

Bed sediments/texture: low flow channel has fine sands and silts, benches to either side comprised of medium sands mostly, likely coarser material at depth, in March 2007 water in channel was more turbid, less clear, than upstream Reach 4.

Bank structure: earthen banks of low flow channel comprised of past deposited sediment (wedge that crossed entire channel), the higher banks rising to the access road slope gently on north side (approx 3:1) and steeper on south side (approx 1:1).

Channel processes: low flow channel contains small flows, larger events flow onto adjacent benches and deposit sandy sediment, uncertain if excavated low flow channel is self sustaining and able to transport sediment or will need additional maintenance.

Biological Conditions

Vegetation Composition: woody riparian vegetation (arroyo and weeping willows) is confined to the toe of the bank and forms a discontinuous band; isolated oaks, eucalyptus, and other upland woody species occur along the top of bank. Canopy closure less than 10% in most places, channel 80% filled with emergent vegetation.

Riparian Corridor: approx 20 ft wide vegetation corridor on each bank dominated by arroyo willow, mature oaks, and eucalyptus.

Instream Habitat: low flow channel provides run/glide habitat, with small riffles, and some deeper pools (3-4 ft deep).

Listed species with potential to occur: Known occurrence of steelhead; potential habitat for western pond turtle.

(c) Lower Reach 3 looking upstream (March 6, 2007).

(d) Lower Reach 3 crossing at Seed Farm Dr. (March 6, 2007).

Management Considerations and Opportunities

Excavation of low flow channel into adjacent sediment benches occurred in 2003 along with extensive vegetation removal. SCWA is monitoring this reach to determine if the low flow channel design is sustainable. Currently (2007), no additional comprehensive maintenance measures are identified. In future, skimming of high benches on other side of the channel may be necessary if those benches aggrade significantly, or low flow channel itself may need occasional dredging of collected sediment. Monitoring and adaptive management will occur on this reach to better identify where and how much deposition continues. This reach does not have significant canopy closure over the channel and would benefit from additional plantings of woody canopy species, if capacity allows.

Copeland Creek – Reach 2

JURISDICTION: City of Rohnert Park owner, SCWA maintenance easement

LOCATION: Seed Farm Drive to Hwy 101

ADJACENT LAND USE: Residential (single family and multi occupancy) to north and south

UPSTREAM: Copeland 3

LENGTH: 3,772 ft

CHANNEL EASEMENT CORRIDOR WIDTH: 127 ft

AVERAGE TOP-OF-BANK WIDTH: 91 ft

(b) Mid Reach 2 looking downstream (March 6, 2007).

MAINTENANCE HISTORY

(a) Reach 2 looking downstream from Seed Farm Dr. (March 6, 2007).

PHYSICAL CONDITIONS

Reach setting: long reach, upper reach has large in-channel bars, aggrading, that alternate along banks (photo b); lower reach has less sinuous deeper channel incised along higher bars (photo c, d).

Active channel: upper/mid reach has sinuous shallow low flow channel (6-8 ft wide), lower reach is a more linear channel, both deeper (2-4 ft) and wider (up to 15 ft) (photo c, d).

Bed sediments/texture: upper/mid reach channel bed/bars are medium sand dominated, downstream channel bed/bars are finer. In March 2007 water in channel was similar in turbidity to Reach 3 and less clear than Reaches 4/5.

Bank structure: upper/mid reach earthen banks of 4-6 ft height (1:1) adjacent to the in-channel sediment wedge and low flow channel (photo b), in lower reach banks are often steeper than 1:1 and 4-6+ ft high (photos c/d).

Channel processes: large low benches and alternating bars of mid reach store aggraded sediment, with occasional pools in main channel, lower reach becomes finer texture depositional environment, increased trash/debris in this reach and moving downstream.

BIOLOGICAL CONDITIONS

Vegetation composition: canopy closure is 25-50%, increasing downstream as the channel narrows and deepens. At breaks in the canopy, cattails grow in isolated patches on bars.

Riparian corridor: A solid band of willows (native Arroyo willows and non-native weeping willows) are found along the toe of the slope throughout the reach. A fringe of emergent wetland vegetation is present adjacent to willows, with rice cutgrass, watercress, and patches of cattails. A mixture of native and non-native trees is present at the top of bank and along the access road, including coast live oak and Monterey pine. The upper banks support shrubby vegetation dominated by non-natives such as Himalaya blackberry and cotoneaster, interspersed with ruderal herbaceous vegetation dominated by Harding grass.

Instream Habitat: channel sinuosity occurs between bars. The channel in the mid-reach is complex with riffles, runs, and isolated pools. Willows provides for additional habitat complexity through rootwads and overhanging roots, which have created a few larger pools with some woody debris.

Listed species with potential to occur: Steelhead are known to occur (reach is a migration corridor); potential habitat for western pond turtle.

(c) Lower Reach 2 looking downstream (March 6, 2007).

(d) Lower Reach 2 looking upstream (March 6, 2007).

MANAGEMENT CONSIDERATIONS AND OPPORTUNITIES

Management considerations include selective bar grading/skimming where necessary, but should include alternating bar forms that provide sinuosity as currently observed (photo b). Other considerations include potential removal of cattails, and planting of more riparian vegetation (if capacity allows) to provide additional shade to retard cattail growth where the canopy is not entirely closed. Though not currently observed, removal of potential vegetation, debris blockages in the lower reach, toward Hwy 101, could be necessary in the future.

Copeland Creek South Fork – Reaches 2 & 1

JURISDICTION: City of Rohnert Park owner, SCWA maintenance easement

LOCATION: Country Club Dr. to Seed Farm Dr.

ADJACENT LAND USE: Residential to east, railroad to west

UPSTREAM: Copeland 3

LENGTH: Reach 2: 738 ft

Reach 1: 2,756 ft

CHANNEL EASEMENT CORRIDOR WIDTH:

Reach 2: 68ft

Reach 1: 86 ft

AVERAGE TOP-OF-BANK WIDTH:

Reach 2: 126 ft

Reach 1: 42 ft

(b) Copeland Creek South Fork (Reach 2) looking upstream (March 6, 2007).

MAINTENANCE HISTORY

(a) Copeland Creek South Fork (Reach 2) looking upstream from Copeland Creek confluence (March 6, 2007).

PHYSICAL CONDITIONS

Reach setting: linear reach adjacent to narrow bench/floodplain that follows railroad alignment, channel was likely formed as the borrow ditch excavated to create railway berm (photo a).

Active channel: single channel 10-12 ft wide at north end, narrows to 6-8 ft at south end (photos a, b), flows observed 1-2 ft deep with occasional deeper pools, channel incised ~3 ft below bench/narrow floodplain on west side.

Bed sediments/texture: appear to be fines and a muddy bottom, with occasional riprap, in March 2007 water in channel was highly turbid, with oil sheen, and other visible poor water quality conditions.

Bank structure: earthen banks of low flow channel comprised of sediment on flat railway bench on west side, steeper bank on east side (~1:1).

Channel processes: low gradient channel has several blockages, both from sediment and vegetation plugs (photo c), in downstream Reach 2 the linear channel form is open water without riffles, bars, or any noticeable channel features.

Biological Conditions

Vegetation composition: 2006-2007 vegetation mapping indicates primarily ruderal vegetation along the banks with some areas of riparian scrub. Large areas of both reaches are filled with emergent vegetation within the ordinary high water mark.

Riparian corridor and canopy: riparian scrub dominates the east bank of Reach 2, no canopy closure over the creek. The rest of Reaches 1 and 2 are dominated by ruderal vegetation along the banks.

Instream habitat: some aquatic and bird habitat provided by cattail/marsh area in lower Reach 1, further upstream channel is choked with cattails, and downstream open channel is straight with few channel features.

Listed species with potential to occur: Potential habitat for western pond turtle.

(c) Copeland Creek South Fork (Reach 1) looking upstream (March 6, 2007).

Management Considerations and Opportunities

Currently, Copeland Creek South Fork (Reach 1) is heavily clogged with cattails (photo c). It is uncertain if additional flow capacity is necessary in this reach and if dredging/removal will be required. Sediment management approaches should explore how to encourage additional trapping and filtering of fine sediments in this reach, which would provide downstream water quality benefits to South Fork Reach 2 and to Copeland Creek Reaches 3 and 2. South Fork (Reach 2) is a more open channel than Reach 1, but suffers from high turbidity and poor visual water quality with oil sheens, etc. Additional measures here that could improve water quality, filter pollutants, and trap fine sediments should be considered. Some type of managed cattail marsh approach may be appropriate as seen in the semi-open channel with cattails in upper Reach 2. Neither South Fork Reach 1 nor 2 have significant canopy closure over the channel and would benefit from additional plantings of woody canopy species, if flow requirements and any special railway requirements allow.

Copeland Creek Restoration Project Monitoring Plan

INTRODUCTION

The purpose of the Copeland Creek Restoration Project Monitoring Plan is to evaluate the effectiveness of the Sonoma County Water Agency's (Agency) efforts to restore fish and wildlife habitat along Copeland Creek. Monitoring actions to be completed are discussed in the Monitoring Plan. This annual report summarizes monitoring data collected during 2001 and 2002. The Copeland Creek Restoration Project site is located along approximately 6,000 linear feet of Copeland Creek between Roberts/Pressley Road and Petaluma Hill Road, east of Sonoma State University, Rohnert Park. Restoration was necessary to minimize creek disturbance due to past land use practices and return the site to more natural conditions. Intensive historic livestock grazing along Copeland Creek degraded aquatic habitat (including habitat for the threatened steelhead), eliminated most bank (riparian) vegetation, accelerated stream bank erosion, and increased channel sedimentation. This monitoring report includes restoration activities and monitoring from the start of the project in 1998 through 2002.

Bank recontouring and stabilization

Restoration Activities

Restoration activities began in 1999 and were completed in phases. Final restoration activities are scheduled for fall 2003. For monitoring purposes the study area was segmented into 5 reaches. Reaches are sequentially numbered from upstream (reach 1) to downstream (reach 5). Restoration activities included fencing, bank recontouring, and native plantings. Fencing was used to restrict agricultural disturbances to the study area and consisted of fencing to exclude cattle from the creek and monument fencing to restrict vineyard maintenance activities. Recontouring was necessary to stabilize degraded stream banks and to remove concrete riprap. In the past concrete debris was dumped along the creek banks at an attempt to stabilize erosion; however, this practice exacerbated the erosion problem. Steep banks and areas with concrete debris were graded to a more stable slope and protected with erosion control fabric and native plants. Also, at high-velocity stream segments the base of the bank was protected with willow sprigs and boulders installed below ground. Native plants were planted along the creek terrace and along recontoured banks. Seed from local riparian and woodland plant species was collected from Crane Creek Park located in an adjacent watershed. Native plants were propagated for 1 or 2 years before planted in the study area.

Installation of erosion control fabric

Native planted with protective tubes

<u>Bank Recontouring</u>

Restoration activities completed include recontouring and stabilization of stream banks in reach 2 and the upper half of reach 5, and planting native vegetation in reach 2 during 1999, reaches 4 and 5 (upper segment) in 2000, and reach 5 (lower segment) in 2002. Recontouring included grading steep banks to a more stable slope and protecting the base of the bank along high-velocity segments with willow sprigs and boulders installed below ground. Also, fencing was installed along reaches 3, 4, and 5 to exclude cattle grazing and agricultural maintenance activities.

Reaches

Restoration in the study reaches included active and/or passive restoration activities. Active restoration consisted of physical changes such as concrete riprap removal and bank recontouring, bank and terrace revegetation, and fencing. Passive restoration involved fencing and the reestablishment of riparian and aquatic habitat from natural processes. Reach 1 was the least disturbed reach and required no recontouring or revegetation. This reach has water most of the year and contained a sparse cover of native riparian vegetation. Also, adjacent landowners previously fenced this reach. Reach 2 required active restoration due to the extensive erosion and braided channel caused by cattle disturbance. Restoration included recontouring and stabilizing stream banks and planting native vegetation. These activities were completed during 1999. Also, reach 2 had been previously fenced. Reach 3 was passively restored because it did not have the extensive erosion problems observed upstream at reach 2. A monument fence was installed in 2001 to restrict vineyard maintenance activities. Reach 3 is expected to recover from natural recruitment of native plants. Reach 4 is a passive restoration area that is temporarily stable from a linear grove of eucalyptus trees along the upper banks and concrete riprap along 150-m-long segment of bank. The landowner has expressed interest in removing the eucalyptus and restoration of the riprap area is scheduled for 2003/04. Fencing was installed in 2000 to exclude cattle grazing and approximately 1,000 native plants were planted on the creek terrace. Reach 5 was an active restoration area requiring extensive recontouring and bank stabilization. Several 100 tons of concrete riprap was removed before the banks could be graded and stabilized. Cattle exclosure fencing was installed along the reach with a 5-m-wide gate between reach 4 to allow the movement of cattle to opposite sides of the creek. Approximately 3,000 native plants were planted on the recontoured banks and upper terrace. Also, planting in reaches 4 and 5 were watered with a temporary irrigation system.

Reach 5 before and 1 year after bank stabilization

STREAM PROFILES

Stream profile monitoring included cross-section and longitudinal surveys (Figures). Cross-section transects provide an elevation profile of the creek and indicated changes in stream bank stability, channel migration, stream scouring, and substrate deposition. Twelve permanent transects where established across Copeland Creek. Two or 3 transects were established in each of the 5 reaches. A longitudinal profile of Copeland Creek establishes the elevation of topographical features along the stream course. The longitudinal profile extends along the thalweg (i.e., centerline) of the creek and is essential for determining the effects of erosion and sediment deposition along the creek. Profile surveys were conducted during 1998 prior to creek restoration and during 2001.

The cross-section and longitudinal profiles show a stream in the early process of stabilization after a century of disturbance. In 1998 four shallow pools were present in the study area. By 2001 eleven shallow to moderately deep pools were present. This increase of pool habitat is a result of curtailing cattle disturbance that causes erosion and allowing natural scouring from flood events to form pools.

Several unstable banks were recontoured to more stable grades to reduce erosion. For example see Figure ___ cross-section S-3 where near vertical banks were recontoured to a 3:1 slope ratio. Also, the longitudinal profile shows a change in thalweg location and areas of erosion and deposition throughout the study area indicating that the stream is still in the process of stabilization. However, the occurrence of shallow, multiple stream courses, caused by past cattle disturbance, has decreased markedly in reaches 1 and 2 (Figure).

Reach 2: Degraded creek with broad multiple channels

WELL MONITORING

Piezometer wells located along the Copeland Creek were used to monitor fluctuations in the shallow ground water levels, important in the survival of riparian plants and the duration of summer creek flows. As shown on Figure __, piezometer wells were installed at four stations along Copeland Creek. Each station consists of a well is situated on the flood plain near the stream channel and a second well on the adjacent terrace to compare ground water at different elevations. The creek at Well 1 located near the upstream end of the study area contains water almost year-round, while Well 4, located at the downstream, contains water typically during winter and spring.

Piezometer wells indicate a similar pattern of groundwater persistence as surface water persistence in Copeland Creek (Figure). Also, terrace wells had relatively lower water levels then corresponding floodplain wells. Groundwater levels and duration decreased with distance downstream. Floodplain Well 1 was the only well that contained water year-round. Wells 2, 3, and 4 had groundwater levels near the surface during late-fall through mid-spring and were dry during the remainder of the year. This water patterns indicates that riparian plant growth and survival may be effected throughout the study area, except along the upper creek. Large plants with deep roots may be able tap deeper groundwater, while sapling plants may not survive the dry summer season or have a slow growth rate until roots can reach a depth to tap summer groundwater levels.

PLANT COMMUNITY/WILDLIFE HABITAT

Vegetation surveys were used to monitor changes in plant communities/wildlife habitats from restoration activities along Copeland Creek. Thirty-six permanent transects were placed perpendicular to the creek channel within the 5 reaches (Figure 1). Data collected at transects were used to determine the frequency of plant species and percent cover of plant communities/ wildlife habitats and to compare changes over time. Vegetation surveys were conducted during 2001 and 2002 during spring when most plants are in bloom.

The vegetation data shows a creek in the early stages recovery from long-term disturbance. Historic cattle grazing eliminated most woody shrub and trees (Figure   Growth form). Most plant species in the study area are herbaceous grasses and forbs (93%) dominated by exotic species, and there are relatively few shrub (4%) and tree (3%) species. There was a similar pattern of species composition among reaches, where the frequency of exotic plant species far outnumbered natives (Figure Native vs Exo by reach). Also, the occurrence of plant communities/wildlife habitat percent cover was similar among reaches and between 2001 and 2002. Because of the similarity between study years, the below data is for 2002 unless otherwise indicated. The limited change between 2 years of sampling is not unexpected at a recently restored site, such as Copeland Creek, due to the time required for woody plants to grow and natural success to occur. For example, a mature riparian forest will likely take decades to develop.

The active channel habitat is in constant annual disturbance from flooding, which maintains a cobble and gravel substrate devoid of most vegetation. This habitat is a dominant feature in the study area due to historic cattle use that destabilized vegetated areas in the flood zone. Active channel ranged from 18% to 45% of the reaches during 2002 (Figure habitat freq). The active channel is expected to decrease in the future as bank stabilization activities reduce erosion and willow scrub and riparian forest species colonizes stream banks and gravel bars.

Reach 1: Natural willow recruitment on gravel bars with nearly perennial water

Willows are a hardy native riparian

species that are often the first species to colonize disturbed stream banks and gravel bars. Willow scrub occurs in all 5 reaches, except in Reach 4 (Figure habitat freq). Willow scrub in reach 1 covered 8% of the reach, which is the highest occurrence in the study area. This high occurrence is likely due to limited historic grazing and nearly year-round water duration in the creek. Reach 2 contained 2% willow scrub from natural recruitment and willow sprig plantings. Reach 3 had 0.5% cover of willow scrub from natural recruitment. Reach 4 probably did not contain willow scrub due to shading from the large eucalyptus trees along the creek. Reach 5 had 2% willow scrub cover from willow sprig plantings. As the willow scrub matures many of the willows will contribute to the development of a riparian forest.

Grassland is the dominant plant community/wildlife habitat in the study area and has been maintained by historic cattle grazing and to a lesser degree recent restoration activities requiring mechanical grading. Grasslands ranged from 49% to 79% of the reaches (Figure habitat freq). Riparian and woodland habitats are expected to replace much of the current grasslands as restoration plantings and natural succession occurs.

Forest and woodland plant communities had a low occurrence in the study area (Figure habitat freq). Oak woodland occurs in reach 3 at 3% of the reach and consists of 2 large valley oak trees. A non-native eucalyptus forest occurs in reach 4 at 28% of the reach. Currently there is no riparian forest in the study area.

Active channel and grassland (foreground) and eucalyptus forest (background)

FISH STUDIES

Stream habitat surveys assessed steelhead habitat along Copeland Creek. These surveys determined habitat used by steelhead, quantified aquatic habitats (i.e., runs, riffles, and pools), and characterized the composition of the streambed (i.e. silt, sand, gravel, cobble, etc.). Streambed substrate is an important indication of stream character and water quality and was used to evaluate salmonid spawning and nursery habitat value. Due to the ephemeral condition of Copeland Creek, fish studies were limited to anecdotal fish observations, relocation of stranded steelhead, and characterizing stream substrate.

Steelhead

Two fish species have been observed in Copeland Creek study area: California roach and steelhead. California roach is a native minnow common to the region and have been found in reaches 1 and 3. Steelhead are known to spawn in the headwaters of Copeland Creek. Because of the seasonal water source in the study area fish do not currently occur year-round. The study area section of Copeland Creek is used by steelhead for migration. Adult steelhead likely migrate upstream through the study area in late winter to spawn in the headwaters, while young steelhead migrate to the ocean in winter or spring. Late migrating young steelhead are occasionally stranded in pools isolated when water flows recede in spring.

On April 30, 2002, 29 steelhead were observed in a pool below a eucalyptus tree in reach 4. These fish ranged in length from 143 to 229 mm fork length and had the brilliant coloration of resident rainbow trout and did not appear to be smolts ready for migration to the ocean. These fish were stranded in a pool located in reach 4 and were relocated to a permanent deep pool upstream approximately 6 km. The pool where the fish were stranded was dry within a week of the rescue. Also, on May 15, 2002, approximately 20 young-of-the-year and 2 one-year-old steelhead were observed in a pool below Petaluma Hill Road located at the downstream end of reach 5.

Creek Substrate

2.3.3 Sediment Sampling

Sediment sampling was conducted utilizing a McNeil sampler (McNeil and Ahnell 1964). The sampler dimensions were 150 mm in diameter and 230 mm deep. The maximum water depth in which collection of river substrate could be collected was 410 mm. The protocol used during the data collection was developed by Valentine (1995). This protocol was adopted for use during the 2000-2001 Biotic Monitoring Program because it allowed the researchers to efficiently process all of the sediment samples in the field, eliminating the need to transport samples back to the lab.

The sampling tube of the McNeil sampler is manually worked into the substrate until the bottom of the sampling basin makes contact with the riverbed. The contents of the sampling tube are removed by hand and placed in the sampling basin. A lid is placed over the top of the sampling tube after all sediment is transferred to retain sediment suspended in the water collected with the sample. The entire contents of the sampler are then transferred to a clean bucket for sieve analysis.

The sample was wet sieved in the field utilizing a series of sieves following a geometric progression (128, 64, 32, 16, 8, 4, 2, 1, 0.5 mm). The sediment was removed from the bucket and passed through the sieves by agitating the sieves by hand and spraying with water. The sediment trapped on each sieve was allowed to drain and was then poured into a 1000 ml graduated cylinder. For materials < 4.0 mm, the sieves were allowed to drip dry for 10 minutes before being placed in the graduated cylinder. A known quantity of water was then added to the cylinder and the sample volume was calculated. The material passing into the pan through the finest sieve (0.5 mm) was poured into Imhoff cones and the suspended material was allowed to settle for exactly 10 minutes. The volume (ml) was then read directly from the cone. The volume of material collected on each sieve was recorded on a field data sheet. Particles retained by the largest sieve (128 mm) are not included in the calculation of the samples metrics. However, all of the particles of this size class were noted on the field data sheets. Measurements of the intermediate axis of the three largest particles collected in a sample were recorded. This information allows analysis of the appropriateness of the sampler core.

Sediment samples were collected from 21 locations in Monitoring Areas 1 and 2 (Appendix D). In Monitoring Area 1, six samples were collected from the mined reach, four from the downstream unmined reach, and four from the upstream unmined reach. In Monitoring Area 2, two samples were collected from the mined reach, three from the downstream unmined reach and two from the upstream unmined reach. As mentioned previously, the maximum depth of the water column at the collection site was 410 mm. This constraint confined sample collection to relatively shallow areas within the reaches. One bulk sample was collected from the thalweg of pool crests at the pool/riffle interfaces. Restricting the sampling sites to pool/riffle breaks was done for two reasons: 1) salmonids preferentially select sites to build redds near the tail-out of a pool or at the head of a riffle (Shapovalov and Taft 1954, Fry 1979, Bjornn and Reiser 1991), and 2) the water velocity is usually greatest at this point during low flow periods thereby reducing the impacts of low flow period sampling on summer accumulations of fine sediment. Because this sampling strategy does not sample from redds which would have some fines winnowed by the action of spawning, the samples collected represent potential spawning gravels. The percent finer values from this data is likely to be greater than those reported by researchers conducting investigations of sediment condition within redds. Curves have been developed to correlate the percent fines in sediment samples collected from potential redd sites to redd gravel (Kondolf 2000). Although these curves were not developed from Russian River data they do provide a mechanism by which correction terms can be applied to the collected data to present a more representative data set depicting the condition of potential spawning substrate within the study area (Appendix D). This allows the comparison of the samples collected during this study to laboratory and field studies conducted on egg survivorship and fry emergence (Kondolf 2000).

The sediment data collected during this study was analyzed to determine several standard variables associated with sediment data. The data collected is presented in three forms: 1) graphically as cumulative frequency curves, 2) the geometric mean, and 3) the Fredle index (Table 14). The term fine sediment refers to particle sizes less than 10 mm in diameter. The percent finer is calculated by tabulating the cumulative percent of material passing through a series of successively smaller sieves. The data developed in the table is then graphed on log-normal graph paper (Appendix C). The resulting cumulative frequency curve can then be used to determine the distribution of particle sizes contained within the sample. The data is log-transformed because it is assumed that sediment samples are log-normally distributed (Valentine 1995, Gordon et al 1992). From the graphs, the 6.4, 4.0, 3.0, 1.0, and 0.85 mm size classes can be extrapolated, as well as the D_{84}, D_{75}, D_{50}, D_{25}, and D_{16} particle sizes. The D_{84} particle size is simply a percentile value of the particle diameter at which 84 percent of the particles in the sample are smaller. D represents the diameter of a particle and the associated number indicates the percentage of a sample smaller, or finer, than that diameter. The D_{75}, D_{50}, D_{25}, and D_{16} particle sizes represent particle diameters at which 75, 50, 25, and 16 percent of the samples are smaller. The D_{75} and D_{25} particles are of particular significance because their values are used to calculate the geometric mean of the samples.

Much research has been conducted assessing the impact of fine sediment on salmonid egg development and fry emergence. Most researchers utilize the percent of material finer than either the 0.85 or 1.0 mm particle sizes in a sample to assess the impact of fine sediment on egg development. Increased amounts of fine particles (<0.85 mm) above 10-20 percent can fill in the interstitial spaces between spawning gravels causing a reduction in respiration rates of salmonids eggs leading to reduction in spawning success (McNeil and Ahnell 1964, McCuddin 1977, Cedreholm and Salo 1979). Tagart (1984, 1986) showed that DO was related inversely to the percentage of fines under 0.85 mm in diameter. His data indicated 32 percent survival to emergence from redds in which less than 20 percent of fines were smaller than 0.85 mm. Survival was only 18 percent from redds that contained more than 20 percent of fines less than 0.85 mm.

Sediments in the 1-10 mm size range have been determined to potentially block fry emergence through intragravel pores (Everest et al. 1987). Three of the more common size classifications used for assessing fry emergent success are the amount of fines less than 3.3 mm (Koski 1966, Moring and Lantz 1974), fines less than 6.4 mm (NCASI 1984, McCuddin 1977), and fines less than 9.5 mm (Tappel and Bjorn 1983). Research has shown that spawning substrate comprised of >30 percent of particles smaller than 6.4 mm (percent finer) can have detrimental effects on emerging salmonid fry (NCASI 1984). Values associated with 50 percent emergence averaged about 30 percent for sediment finer than both 3.35 mm and 6.35 mm (Kondolf 2000). Particles of this size and quantity can seal salmonid spawning gravels, effectively entombing emerging fry (Bjornn and Reiser 1991).

Although percent concentration of fines has historically been an accepted indicator of the quality of salmonid spawning substrate, other calculations can be made utilizing the sediment data to predict the percent survival from egg to fry emergence. The two most commonly used calculations are the geometric mean and the fredle index. Both the geometric mean and the fredle index can be utilized to predict the percent survival from egg to fry emergence. For steelhead, overall survival from egg deposition to emergence ranges from 29.8 percent in substrates containing high levels of fine material, to 79.9 percent in substrates containing low levels of fine material. Under favorable conditions survival to emergence is high, ranging between 70 and 85 percent of the eggs deposited (Shapovalov and Taft 1954).

The geometric mean (D_g) is the mean diameter of particles in gravel samples and serves as another descriptor of substrate composition (Platts et al. 1979). Platts defined geometric mean diameter (D_g) as;

$$D_g = (D_{16}\ D_{84})^{1/2}$$

Chapman (1988) plotted survival in relation to D_g together with linear regressions of survival to emergence on D_g for Koski's (1966) data for natural coho salmon redds and from laboratory data on sockeye salmon (Cooper 1965) and steelhead and chinook salmon (Tappel and Bjornn 1983). Chapman found the regressions, all significant (r^2 = 0.46-0.83), did not conform to the model of Shirazi et al. (1981). He concluded that the use of the Shirazi et al. (1981) model was not appropriate to depict survival of salmonids in relation to D_g.

Chapman (1988) determined that the formula of Lotspeich and Everest (1981) provided a slightly more accurate estimate of D_g than the formula of Platts et al. (1981). The Lotspeich and Everest (1981) formula was used in the calculation of the geometric means presented in this study.

Lotspeich and Everest (1981) calculated D_g as:

$$D_g = D_1^{w1} \text{ x } D_2^{w2} \text{ x } \ldots \text{ x } D_n^{wn};$$

Where: D_g = the geometric mean
D = midpoint diameter of particles retained by a given sieve and the next larger sieve,
w = decimal fraction by volume retained by a given sieve, and
n = the number of sieves used, inclusive of the pan.

Another measure of central tendency, the Fredle index (f_i), was developed as a predictor of egg survival to emergence (Lotspeich and Everest 1981). The Fredle index relates mean particle diameter (such as geometric mean) to its variance. Lotspeich and Everest (1981) related the fredle index to survival to emergence of steelhead and coho salmon. Using the data from Phillips et al. (1975), Lotspeich and Everest (1981) showed a strong correlation between salmonid survival and the Fredle index. Chapman (1988) calculated f_i for the data of Tappel and Bjornn (1983) and found highly significant regressions (r^2 = 0.85 for chinook salmon and 0.95 for steelhead) of survival on f_i between f_i = 1.0 and f_i = 4.0. At f_i = 5.0 and above, survival to emergence exceeded 90 percent for both chinook salmon and steelhead. The Fredle index is calculated as:

$$f_i = D_g/[\ D_{75}/\ D_{25}]^{½}$$

where: D_g = the geometric mean as calculated previously, and
D_{75} and D_{25} = as estimated from the graphs

REPTILES AND AMPHIBIANS

Monitoring restoration of Copeland Creek included surveying for reptiles and amphibians (collectively referred to as herps) to evaluate the effects of habitat restoration on these species. Restoration is expected to enhance habitat for several native frog, salamander, lizard, snake, and turtle species. Survey methods included visual searches and pitfall trapping. Daytime visual surveys consisted of walking the creek banks in the morning during the spring and summer searching for herps along the 5 reaches. Visual surveys were conducted on 5 days during 2001 (26 April, 10 May, 12 June, 27 August, and 5 September) and on 7 days during 2002 (15 April, 2 May, 15 May, 23 May, 24 July, 8 August, and 15 August). Pitfall trapping was used to identify herp species that are often missed during visual surveys. Four trap arrays (consisting of 8-m-long drift fence with 35-cm-deep pitfall traps at each end) were installed in each of the 5 reaches totally 20 arrays. Half of the arrays were placed along the stream bank within the flood zone and the other half in grasslands along the creek terrace. Trapping was conducted on 5 days during early summer in 2001 (13-15 and 26-27 June) and 8 days during late spring in 2002 (16-17, 22-23 May and 11-14 June). Also, western fence lizard was the most common species captured in traps, which provided information on the size and age structure of this common species.

Sonoma County has an abundance of amphibian and reptile species and 26 out of 33 (79%) of these species likely occur in the Copeland Creek watershed (Table __). Currently, there are 11 known herp species in the study area and there is a higher diversity of species in the upper study area (reaches 1, 2, and 3) then in the lower study area (reaches 4 and 5) probably due to the increased persistence of water and higher habitat complexity in the upper study area (Figure Sp Diversity). The species types observed varied by the 2 survey techniques used (Figure 2 techniques). Most snakes and frogs/toads species were reported from visual surveys, while most lizard species were observed from trap surveys. Table __ summarizes average herp observations during visual surveys.

Amphibian populations naturally fluctuate from annual climate changes. Typically, during wet years large numbers of amphibians breed and a relatively large portion of their offspring survive to maturity, while in dry years few animals breed and offspring survival is relatively low. Precipitation during 2001 was below normal, which likely restricted amphibian breeding. In 2002 rainfall was above normal; however, most of the rainfall was early in the season and Copeland Creek dried at a rate similar to 2001. It is anticipated that as native habitats are restored the existing xeric (dry) habitats consisting of grasslands and dry streambed will be partially replaced with mesic (moist) habitats such as oak woodland, riparian forest, and willow scrub, and a perennial creek.

The current distribution of the foothill yellow-legged frog in the study area appears to be restricted upper reach due to the limited source of permanent water. Foothill yellow-legged frog prefers perennial water and water persistence through late-summer is required for tadpoles to metamorphose (Figures FYLF). Two foothill yellow-legged frog egg masses and 100s of tadpoles were found during 2001; however, the creek dried in mid-summer and no tadpoles survived. During 2002 a similar production of egg masses and tadpoles were observed, pools in reach 1 remained hydrated through late summer, and juvenile foothill yellow-legged frogs were observed.

The western toad showed a similar reproductive success pattern as the foothill yellow-legged frog and a breeding distribution that varied annually (Figure toad). Western toads are capable of breeding in intermittent pools that hold water until mid-summer and potential breeding habitat for the toad occurs throughout the study area. Toads spawned in reaches 1, 2, and 3 during 2001 but no tadpoles survived due to early creek drying. During 2002 spawning occurred in all 5 reaches. However, as observed with the foothill yellow-legged frog, metamorphosis only occurred in reach 1 where water persisted throughout most of the summer. Restoration of riparian habitat is expected to increase the persistence of water and deep pools from increased shading and the formation of scour pools throughout the study area. This restoration is expected to increase breeding habitat from frogs and toads in the lower reaches of Copeland Creek and increase reproductive success of both species.

Western fence lizard was most abundant herp species observed in the study area and was found in all 5 reaches (Figure liz dist.). This lizard is a hardy terrestrial species that can colonize disturbed habitats, such as a stream degraded by historic cattle grazing. Similar numbers of western fence lizard were observed in each reach during our 2001 and 2002 surveys, except for reach 5 (Figure liz dist). Reach 5 was restored using active restoration techniques between field survey seasons in 2001 and 2002. Mechanical grading activities associated with recontouring the stream banks temporarily increased habitat for the western fence lizard. It is anticipated that as native habitats are restored in the study area and disturbed habitats decrease so will western fence lizard numbers.

Copeland Creek Restoration Project Monitoring Plan

INTRODUCTION

The purpose of the Copeland Creek Restoration Project Monitoring Plan is to evaluate the effectiveness of the Sonoma County Water Agency's (Agency) efforts to restore fish and wildlife habitat along Copeland Creek. Monitoring actions to be completed are discussed in the Monitoring Plan. This annual report summarizes monitoring data collected during 2001 and 2002. The Copeland Creek Restoration Project site is located along approximately 6,000 linear feet of Copeland Creek between Roberts/Pressley Road and Petaluma Hill Road, east of Sonoma State University, Rohnert Park. Restoration was necessary to minimize creek disturbance due to past land use practices and return the site to more natural conditions. Intensive historic livestock grazing along Copeland Creek degraded aquatic habitat (including habitat for the threatened steelhead), eliminated most bank (riparian) vegetation, accelerated stream bank erosion, and increased channel sedimentation. This monitoring report includes restoration activities and monitoring from the start of the project in 1998 through 2002.

Bank recontouring and stabilization

Restoration Activities

Restoration activities began in 1999 and were completed in phases. Final restoration activities are scheduled for fall 2003. For monitoring purposes the study area was segmented into 5 reaches. Reaches are sequentially numbered from upstream (reach 1) to downstream (reach 5). Restoration activities included fencing, bank recontouring, and native plantings. Fencing was used to restrict agricultural disturbances to the study area and consisted of fencing to exclude cattle from the creek and monument fencing to restrict vineyard maintenance activities. Recontouring was necessary to stabilize degraded stream banks and to remove concrete riprap. In the past concrete debris was dumped along the creek banks at an attempt to stabilize erosion; however, this practice exacerbated the erosion problem. Steep banks and areas with concrete debris were graded to a more stable slope and protected with erosion control fabric and native plants. Also, at high-velocity stream segments the base of the bank was protected with willow sprigs and boulders installed below ground. Native plants were planted along the creek terrace and along recontoured banks. Seed from local riparian and woodland plant species was collected from Crane Creek Park located in an adjacent watershed. Native plants were propagated for 1 or 2 years before planted in the study area.

Installation of erosion control fabric

Native planted with protective tubes

<u>Bank Recontouring</u>

Restoration activities completed include recontouring and stabilization of stream banks in reach 2 and the upper half of reach 5, and planting native vegetation in reach 2 during 1999, reaches 4 and 5 (upper segment) in 2000, and reach 5 (lower segment) in 2002. Recontouring included grading steep banks to a more stable slope and protecting the base of the bank along high-velocity segments with willow sprigs and boulders installed below ground. Also, fencing was installed along reaches 3, 4, and 5 to exclude cattle grazing and agricultural maintenance activities.

Reaches

Restoration in the study reaches included active and/or passive restoration activities. Active restoration consisted of physical changes such as concrete riprap removal and bank recontouring, bank and terrace revegetation, and fencing. Passive restoration involved fencing and the reestablishment of riparian and aquatic habitat from natural processes. Reach 1 was the least disturbed reach and required no recontouring or revegetation. This reach has water most of the year and contained a sparse cover of native riparian vegetation. Also, adjacent landowners previously fenced this reach. Reach 2 required active restoration due to the extensive erosion and braided channel caused by cattle disturbance. Restoration included recontouring and stabilizing stream banks and planting native vegetation. These activities were completed during 1999. Also, reach 2 had been previously fenced. Reach 3 was passively restored because it did not have the extensive erosion problems observed upstream at reach 2. A monument fence was installed in 2001 to restrict vineyard maintenance activities. Reach 3 is expected to recover from natural recruitment of native plants. Reach 4 is a passive restoration area that is temporarily stable from a linear grove of eucalyptus trees along the upper banks and concrete riprap along 150-m-long segment of bank. The landowner has expressed interest in removing the eucalyptus and restoration of the riprap area is scheduled for 2003/04. Fencing was installed in 2000 to exclude cattle grazing and approximately 1,000 native plants were planted on the creek terrace. Reach 5 was an active restoration area requiring extensive recontouring and bank stabilization. Several 100 tons of concrete riprap was removed before the banks could be graded and stabilized. Cattle exclosure fencing was installed along the reach with a 5-m-wide gate between reach 4 to allow the movement of cattle to opposite sides of the creek. Approximately 3,000 native plants were planted on the recontoured banks and upper terrace. Also, planting in reaches 4 and 5 were watered with a temporary irrigation system.

Reach 5 before and 1 year after bank stabilization

STREAM PROFILES

Stream profile monitoring included cross-section and longitudinal surveys (Figures). Cross-section transects provide an elevation profile of the creek and indicated changes in stream bank stability, channel migration, stream scouring, and substrate deposition. Twelve permanent transects where established across Copeland Creek. Two or 3 transects were established in each of the 5 reaches. A longitudinal profile of Copeland Creek establishes the elevation of topographical features along the stream course. The longitudinal profile extends along the thalweg (i.e., centerline) of the creek and is essential for determining the effects of erosion and sediment deposition along the creek. Profile surveys were conducted during 1998 prior to creek restoration and during 2001.

The cross-section and longitudinal profiles show a stream in the early process of stabilization after a century of disturbance. In 1998 four shallow pools were present in the study area. By 2001 eleven shallow to moderately deep pools were present. This increase of pool habitat is a result of curtailing cattle disturbance that causes erosion and allowing natural scouring from flood events to form pools.

Several unstable banks were recontoured to more stable grades to reduce erosion. For example see Figure ___ cross-section S-3 where near vertical banks were recontoured to a 3:1 slope ratio. Also, the longitudinal profile shows a change in thalweg location and areas of erosion and deposition throughout the study area indicating that the stream is still in the process of stabilization. However, the occurrence of shallow, multiple stream courses, caused by past cattle disturbance, has decreased markedly in reaches 1 and 2 (Figure).

Reach 2: Degraded creek with broad multiple channels

WELL MONITORING

Piezometer wells located along the Copeland Creek were used to monitor fluctuations in the shallow ground water levels, important in the survival of riparian plants and the duration of summer creek flows. As shown on Figure __, piezometer wells were installed at four stations along Copeland Creek. Each station consists of a well is situated on the flood plain near the stream channel and a second well on the adjacent terrace to compare ground water at different elevations. The creek at Well 1 located near the upstream end of the study area contains water almost year-round, while Well 4, located at the downstream, contains water typically during winter and spring.

Piezometer wells indicate a similar pattern of groundwater persistence as surface water persistence in Copeland Creek (Figure). Also, terrace wells had relatively lower water levels then corresponding floodplain wells. Groundwater levels and duration decreased with distance downstream. Floodplain Well 1 was the only well that contained water year-round. Wells 2, 3, and 4 had groundwater levels near the surface during late-fall through mid-spring and were dry during the remainder of the year. This water patterns indicates that riparian plant growth and survival may be effected throughout the study area, except along the upper creek. Large plants with deep roots may be able tap deeper groundwater, while sapling plants may not survive the dry summer season or have a slow growth rate until roots can reach a depth to tap summer groundwater levels.

PLANT COMMUNITY/WILDLIFE HABITAT

Vegetation surveys were used to monitor changes in plant communities/wildlife habitats from restoration activities along Copeland Creek. Thirty-six permanent transects were placed perpendicular to the creek channel within the 5 reaches (Figure 1). Data collected at transects were used to determine the frequency of plant species and percent cover of plant communities/ wildlife habitats and to compare changes over time. Vegetation surveys were conducted during 2001 and 2002 during spring when most plants are in bloom.

The vegetation data shows a creek in the early stages recovery from long-term disturbance. Historic cattle grazing eliminated most woody shrub and trees (Figure   Growth form). Most plant species in the study area are herbaceous grasses and forbs (93%) dominated by exotic species, and there are relatively few shrub (4%) and tree (3%) species. There was a similar pattern of species composition among reaches, where the frequency of exotic plant species far outnumbered natives (Figure Native vs Exo by reach). Also, the occurrence of plant communities/wildlife habitat percent cover was similar among reaches and between 2001 and 2002. Because of the similarity between study years, the below data is for 2002 unless otherwise indicated. The limited change between 2 years of sampling is not unexpected at a recently restored site, such as Copeland Creek, due to the time required for woody plants to grow and natural success to occur. For example, a mature riparian forest will likely take decades to develop.

Reach 1: Natural willow recruitment on gravel bars with nearly perennial water

The active channel habitat is in constant annual disturbance from flooding, which maintains a cobble and gravel substrate devoid of most vegetation. This habitat is a dominant feature in the study area due to historic cattle use that destabilized vegetated areas in the flood zone. Active channel ranged from 18% to 45% of the reaches during 2002 (Figure habitat freq). The active channel is expected to decrease in the future as bank stabilization activities reduce erosion and willow scrub and riparian forest species colonizes stream banks and gravel bars.

Willows are a hardy native riparian

species that are often the first species to colonize disturbed stream banks and gravel bars. Willow scrub occurs in all 5 reaches, except in Reach 4 (Figure habitat freq). Willow scrub in reach 1 covered 8% of the reach, which is the highest occurrence in the study area. This high occurrence is likely due to limited historic grazing and nearly year-round water duration in the creek. Reach 2 contained 2% willow scrub from natural recruitment and willow sprig plantings. Reach 3 had 0.5% cover of willow scrub from natural recruitment. Reach 4 probably did not contain willow scrub due to shading from the large eucalyptus trees along the creek. Reach 5 had 2% willow scrub cover from willow sprig plantings. As the willow scrub matures many of the willows will contribute to the development of a riparian forest.

Grassland is the dominant plant community/wildlife habitat in the study area and has been maintained by historic cattle grazing and to a lesser degree recent restoration activities requiring mechanical grading. Grasslands ranged from 49% to 79% of the reaches (Figure habitat freq). Riparian and woodland habitats are expected to replace much of the current grasslands as restoration plantings and natural succession occurs.

Forest and woodland plant communities had a low occurrence in the study area (Figure habitat freq). Oak woodland occurs in reach 3 at 3% of the reach and consists of 2 large valley oak trees. A non-native eucalyptus forest occurs in reach 4 at 28% of the reach. Currently there is no riparian forest in the study area.

Active channel and grassland (foreground) and eucalyptus forest (background)

FISH STUDIES

Stream habitat surveys assessed steelhead habitat along Copeland Creek. These surveys determined habitat used by steelhead, quantified aquatic habitats (i.e., runs, riffles, and pools), and characterized the composition of the streambed (i.e. silt, sand, gravel, cobble, etc.). Streambed substrate is an important indication of stream character and water quality and was used to evaluate salmonid spawning and nursery habitat value. Due to the ephemeral condition of Copeland Creek, fish studies were limited to anecdotal fish observations, relocation of stranded steelhead, and characterizing stream substrate.

Steelhead

Two fish species have been observed in Copeland Creek study area: California roach and steelhead. California roach is a native minnow common to the region and have been found in reaches 1 and 3. Steelhead are known to spawn in the headwaters of Copeland Creek. Because of the seasonal water source in the study area fish do not currently occur year-round. The study area section of Copeland Creek is used by steelhead for migration. Adult steelhead likely migrate upstream through the study area in late winter to spawn in the headwaters, while young steelhead migrate to the ocean in winter or spring. Late migrating young steelhead are occasionally stranded in pools isolated when water flows recede in spring.

On April 30, 2002, 29 steelhead were observed in a pool below a eucalyptus tree in reach 4. These fish ranged in length from 143 to 229 mm fork length and had the brilliant coloration of resident rainbow trout and did not appear to be smolts ready for migration to the ocean. These fish were stranded in a pool located in reach 4 and were relocated to a permanent deep pool upstream approximately 6 km. The pool where the fish were stranded was dry within a week of the rescue. Also, on May 15, 2002, approximately 20 young-of-the-year and 2 one-year-old steelhead were observed in a pool below Petaluma Hill Road located at the downstream end of reach 5.

Creek Substrate

2.3.3 Sediment Sampling

Sediment sampling was conducted utilizing a McNeil sampler (McNeil and Ahnell 1964). The sampler dimensions were 150 mm in diameter and 230 mm deep. The maximum water depth in which collection of river substrate could be collected was 410 mm. The protocol used during the data collection was developed by Valentine (1995). This protocol was adopted for use during the 2000-2001 Biotic Monitoring Program because it allowed the researchers to efficiently process all of the sediment samples in the field, eliminating the need to transport samples back to the lab.

The sampling tube of the McNeil sampler is manually worked into the substrate until the bottom of the sampling basin makes contact with the riverbed. The contents of the sampling tube are removed by hand and placed in the sampling basin. A lid is placed over the top of the sampling tube after all sediment is transferred to retain sediment suspended in the water collected with the sample. The entire contents of the sampler are then transferred to a clean bucket for sieve analysis.

The sample was wet sieved in the field utilizing a series of sieves following a geometric progression (128, 64, 32, 16, 8, 4, 2, 1, 0.5 mm). The sediment was removed from the bucket and passed through the sieves by agitating the sieves by hand and spraying with water. The sediment trapped on each sieve was allowed to drain and was then poured into a 1000 ml graduated cylinder. For materials < 4.0 mm, the sieves were allowed to drip dry for 10 minutes before being placed in the graduated cylinder. A known quantity of water was then added to the cylinder and the sample volume was calculated. The material passing into the pan through the finest sieve (0.5 mm) was poured into Imhoff cones and the suspended material was allowed to settle for exactly 10 minutes. The volume (ml) was then read directly from the cone. The volume of material collected on each sieve was recorded on a field data sheet. Particles retained by the largest sieve (128 mm) are not included in the calculation of the samples metrics. However, all of the particles of this size class were noted on the field data sheets. Measurements of the intermediate axis of the three largest particles collected in a sample were recorded. This information allows analysis of the appropriateness of the sampler core.

Sediment samples were collected from 21 locations in Monitoring Areas 1 and 2 (Appendix D). In Monitoring Area 1, six samples were collected from the mined reach, four from the downstream unmined reach, and four from the upstream unmined reach. In Monitoring Area 2, two samples were collected from the mined reach, three from the downstream unmined reach and two from the upstream unmined reach. As mentioned previously, the maximum depth of the water column at the collection site was 410 mm. This constraint confined sample collection to relatively shallow areas within the reaches. One bulk sample was collected from the thalweg of pool crests at the pool/riffle interfaces. Restricting the sampling sites to pool/riffle breaks was done for two reasons: 1) salmonids preferentially select sites to build redds near the tail-out of a pool or at the head of a riffle (Shapovalov and Taft 1954, Fry 1979, Bjornn and Reiser 1991), and 2) the water velocity is usually greatest at this point during low flow periods thereby reducing the impacts of low flow period sampling on summer accumulations of fine sediment. Because this sampling strategy does not sample from redds which would have some fines winnowed by the action of spawning, the samples collected represent potential spawning gravels. The percent finer values from this data is likely to be greater than those reported by researchers conducting investigations of sediment condition within redds. Curves have been developed to correlate the percent fines in sediment samples collected from potential redd sites to redd gravel (Kondolf 2000). Although these curves were not developed from Russian River data they do provide a mechanism by which correction terms can be applied to the collected data to present a more representative data set depicting the condition of potential spawning substrate within the study area (Appendix D). This allows the comparison of the samples collected during this study to laboratory and field studies conducted on egg survivorship and fry emergence (Kondolf 2000).

The sediment data collected during this study was analyzed to determine several standard variables associated with sediment data. The data collected is presented in three forms: 1) graphically as cumulative frequency curves, 2) the geometric mean, and 3) the Fredle index (Table 14). The term fine sediment refers to particle sizes less than 10 mm in diameter. The percent finer is calculated by tabulating the cumulative percent of material passing through a series of successively smaller sieves. The data developed in the table is then graphed on log-normal graph paper (Appendix C). The resulting cumulative frequency curve can then be used to determine the distribution of particle sizes contained within the sample. The data is log-transformed because it is assumed that sediment samples are log-normally distributed (Valentine 1995, Gordon et al 1992). From the graphs, the 6.4, 4.0, 3.0, 1.0, and 0.85 mm size classes can be extrapolated, as well as the D_{84}, D_{75}, D_{50}, D_{25}, and D_{16} particle sizes. The D_{84} particle size is simply a percentile value of the particle diameter at which 84 percent of the particles in the sample are smaller. D represents the diameter of a particle and the associated number indicates the percentage of a sample smaller, or finer, than that diameter. The D_{75}, D_{50}, D_{25}, and D_{16} particle sizes represent particle diameters at which 75, 50, 25, and 16 percent of the samples are smaller. The D_{75} and D_{25} particles are of particular significance because their values are used to calculate the geometric mean of the samples.

Much research has been conducted assessing the impact of fine sediment on salmonid egg development and fry emergence. Most researchers utilize the percent of material finer than either the 0.85 or 1.0 mm particle sizes in a sample to assess the impact of fine sediment on egg development. Increased amounts of fine particles (<0.85 mm) above 10-20 percent can fill in the interstitial spaces between spawning gravels causing a reduction in respiration rates of salmonids eggs leading to reduction in spawning success (McNeil and Ahnell 1964, McCuddin 1977, Cedreholm and Salo 1979). Tagart (1984, 1986) showed that DO was related inversely to the percentage of fines under 0.85 mm in diameter. His data indicated 32 percent survival to emergence from redds in which less than 20 percent of fines were smaller than 0.85 mm. Survival was only 18 percent from redds that contained more than 20 percent of fines less than 0.85 mm.

Sediments in the 1-10 mm size range have been determined to potentially block fry emergence through intragravel pores (Everest et al. 1987). Three of the more common size classifications used for assessing fry emergent success are the amount of fines less than 3.3 mm (Koski 1966, Moring and Lantz 1974), fines less than 6.4 mm (NCASI 1984, McCuddin 1977), and fines less than 9.5 mm (Tappel and Bjorn 1983). Research has shown that spawning substrate comprised of >30 percent of particles smaller than 6.4 mm (percent finer) can have detrimental effects on emerging salmonid fry (NCASI 1984). Values associated with 50 percent emergence averaged about 30 percent for sediment finer than both 3.35 mm and 6.35 mm (Kondolf 2000). Particles of this size and quantity can seal salmonid spawning gravels, effectively entombing emerging fry (Bjornn and Reiser 1991).

Although percent concentration of fines has historically been an accepted indicator of the quality of salmonid spawning substrate, other calculations can be made utilizing the sediment data to predict the percent survival from egg to fry emergence. The two most commonly used calculations are the geometric mean and the fredle index. Both the geometric mean and the fredle index can be utilized to predict the percent survival from egg to fry emergence. For steelhead, overall survival from egg deposition to emergence ranges from 29.8 percent in substrates containing high levels of fine material, to 79.9 percent in substrates containing low levels of fine material. Under favorable conditions survival to emergence is high, ranging between 70 and 85 percent of the eggs deposited (Shapovalov and Taft 1954).

The geometric mean (D_g) is the mean diameter of particles in gravel samples and serves as another descriptor of substrate composition (Platts et al. 1979). Platts defined geometric mean diameter (D_g) as;

$$D_g = (D_{16}\ D_{84})^{1/2}$$

Chapman (1988) plotted survival in relation to D_g together with linear regressions of survival to emergence on D_g for Koski's (1966) data for natural coho salmon redds and from laboratory data on sockeye salmon (Cooper 1965) and steelhead and chinook salmon (Tappel and Bjornn 1983). Chapman found the regressions, all significant (r^2 = 0.46-0.83), did not conform to the model of Shirazi et al. (1981). He concluded that the use of the Shirazi et al. (1981) model was not appropriate to depict survival of salmonids in relation to D_g.

Chapman (1988) determined that the formula of Lotspeich and Everest (1981) provided a slightly more accurate estimate of D_g than the formula of Platts et al. (1981). The Lotspeich and Everest (1981) formula was used in the calculation of the geometric means presented in this study.

Lotspeich and Everest (1981) calculated D_g as:

$$D_g = D_1^{w1} \times D_2^{w2} \times \ldots \times D_n^{wn};$$

Where: D_g = the geometric mean
D = midpoint diameter of particles retained by a given sieve and the next larger sieve,
w = decimal fraction by volume retained by a given sieve, and
n = the number of sieves used, inclusive of the pan.

Another measure of central tendency, the Fredle index (f_i), was developed as a predictor of egg survival to emergence (Lotspeich and Everest 1981). The Fredle index relates mean particle diameter (such as geometric mean) to its variance. Lotspeich and Everest (1981) related the fredle index to survival to emergence of steelhead and coho salmon. Using the data from Phillips et al. (1975), Lotspeich and Everest (1981) showed a strong correlation between salmonid survival and the Fredle index. Chapman (1988) calculated f_i for the data of Tappel and Bjornn (1983) and found highly significant regressions (r^2 = 0.85 for chinook salmon and 0.95 for steelhead) of survival on f_i between f_i = 1.0 and f_i = 4.0. At f_i = 5.0 and above, survival to emergence exceeded 90 percent for both chinook salmon and steelhead. The Fredle index is calculated as:

$$f_i = D_g/[\ D_{75}/\ D_{25}]^{1/2}$$

where: D_g = the geometric mean as calculated previously, and
D_{75} and D_{25} = as estimated from the graphs

REPTILES AND AMPHIBIANS

Monitoring restoration of Copeland Creek included surveying for reptiles and amphibians (collectively referred to as herps) to evaluate the effects of habitat restoration on these species. Restoration is expected to enhance habitat for several native frog, salamander, lizard, snake, and turtle species. Survey methods included visual searches and pitfall trapping. Daytime visual surveys consisted of walking the creek banks in the morning during the spring and summer searching for herps along the 5 reaches. Visual surveys were conducted on 5 days during 2001 (26 April, 10 May, 12 June, 27 August, and 5 September) and on 7 days during 2002 (15 April, 2 May, 15 May, 23 May, 24 July, 8 August, and 15 August). Pitfall trapping was used to identify herp species that are often missed during visual surveys. Four trap arrays (consisting of 8-m-long drift fence with 35-cm-deep pitfall traps at each end) were installed in each of the 5 reaches totally 20 arrays. Half of the arrays were placed along the stream bank within the flood zone and the other half in grasslands along the creek terrace. Trapping was conducted on 5 days during early summer in 2001 (13-15 and 26-27 June) and 8 days during late spring in 2002 (16-17, 22-23 May and 11-14 June). Also, western fence lizard was the most common species captured in traps, which provided information on the size and age structure of this common species.

Sonoma County has an abundance of amphibian and reptile species and 26 out of 33 (79%) of these species likely occur in the Copeland Creek watershed (Table __). Currently, there are 11 known herp species in the study area and there is a higher diversity of species in the upper study area (reaches 1, 2, and 3) then in the lower study area (reaches 4 and 5) probably due to the increased persistence of water and higher habitat complexity in the upper study area (Figure Sp Diversity). The species types observed varied by the 2 survey techniques used (Figure 2 techniques). Most snakes and frogs/toads species were reported from visual surveys, while most lizard species were observed from trap surveys. Table __ summarizes average herp observations during visual surveys.

Amphibian populations naturally fluctuate from annual climate changes. Typically, during wet years large numbers of amphibians breed and a relatively large portion of their offspring survive to maturity, while in dry years few animals breed and offspring survival is relatively low. Precipitation during 2001 was below normal, which likely restricted amphibian breeding. In 2002 rainfall was above normal; however, most of the rainfall was early in the season and Copeland Creek dried at a rate similar to 2001. It is anticipated that as native habitats are restored the existing xeric (dry) habitats consisting of grasslands and dry streambed will be partially replaced with mesic (moist) habitats such as oak woodland, riparian forest, and willow scrub, and a perennial creek.

The current distribution of the foothill yellow-legged frog in the study area appears to be restricted upper reach due to the limited source of permanent water. Foothill yellow-legged frog prefers perennial water and water persistence through late-summer is required for tadpoles to metamorphose (Figures FYLF). Two foothill yellow-legged frog egg masses and 100s of tadpoles were found during 2001; however, the creek dried in mid-summer and no tadpoles survived. During 2002 a similar production of egg masses and tadpoles were observed, pools in reach 1 remained hydrated through late summer, and juvenile foothill yellow-legged frogs were observed.

The western toad showed a similar reproductive success pattern as the foothill yellow-legged frog and a breeding distribution that varied annually (Figure toad). Western toads are capable of breeding in intermittent pools that hold water until mid-summer and potential breeding habitat for the toad occurs throughout the study area. Toads spawned in reaches 1, 2, and 3 during 2001 but no tadpoles survived due to early creek drying. During 2002 spawning occurred in all 5 reaches. However, as observed with the foothill yellow-legged frog, metamorphosis only occurred in reach 1 where water persisted throughout most of the summer. Restoration of riparian habitat is expected to increase the persistence of water and deep pools from increased shading and the formation of scour pools throughout the study area. This restoration is expected to increase breeding habitat from frogs and toads in the lower reaches of Copeland Creek and increase reproductive success of both species.

Western fence lizard was most abundant herp species observed in the study area and was found in all 5 reaches (Figure liz dist.). This lizard is a hardy terrestrial species that can colonize disturbed habitats, such as a stream degraded by historic cattle grazing. Similar numbers of western fence lizard were observed in each reach during our 2001 and 2002 surveys, except for reach 5 (Figure liz dist). Reach 5 was restored using active restoration techniques between field survey seasons in 2001 and 2002. Mechanical grading activities associated with recontouring the stream banks temporarily increased habitat for the western fence lizard. It is anticipated that as native habitats are restored in the study area and disturbed habitats decrease so will western fence lizard numbers.

Design of Low-Flow Channels

by Craig Fischenich[1]

August 2002

Complexity	***Value as a Planning Tool***	***Cost***
Low Moderate High	Low Moderate High	Low Moderate High

OVERVIEW

Maintenance or restoration of physical aquatic habitat in streams during critical periods can often be accommodated with the development of low-flow channels, designed to concentrate flows and increase channel velocity and depth during low-flow periods. A procedure for the first-order approximation of a stable low-flow channel form based upon physical reasoning, empirical evidence, and constraints common to low-flow channel projects is presented in this technical note. Topics discussed include simplifying assumptions, limitations, and applicability.

PLANNING

Unaltered natural streams support healthy aquatic ecosystems due largely to their habitat complexity. Alternate pools and riffles, irregular planforms, eroding banks, overhanging vegetation, boulders, logs, and variable substrate all contribute to diversity of habitat within and along the channel. Natural channels are scaled to provide this diversity for a wide range of flow conditions.

In contrast, channels modified for flood control often have relatively uniform depths and velocities and usually contain few instream and streambank features that provide habitat. The same situation arises for urban streams that have enlarged due to increased runoff; they are "overfit" during baseflow conditions and display small, featureless channels. This lack of diversity in modified and enlarged channels negatively influences the aquatic ecosystem.

Attaining habitat diversity in such channels requires the incorporation of instream and streambank features and cover devices that create depth, velocity, and cover diversity. These features are most effective when they contribute to natural and diverse channel conditions during low flow but have little impact upon the ability of the channel to convey flood flows and sediment. Furthermore, these features must possess the necessary stability to withstand the high velocities typically associated with modified channels. A successful design concept that improves habitat conditions but has negligible effects upon flooding is the combination of streambank and instream features to form a diverse, stable, low-flow channel (Figure 1).

Figure 1. Low-flow channels can maintain natural stream characteristics within an enlarged floodway

[1] USAE Research and Development Center, Environmental Laboratory, 3909 Halls Ferry Rd., Vicksburg MS 39180

Restoration of physical aquatic habitat in streams during critical periods can often be accomplished with low-flow channels designed to concentrate flows, increase channel velocity and depth, and generally maintain the characteristics of a natural channel within an enlarged flood control channel. Structural measures such as bank protection, flow deflectors, and sills are generally required to stabilize the channel and provide habitat diversity. In addition to the usual design requirements for these structures, a structural layout is needed that allows the stream to adopt a form consistent with the project objectives. Designers must translate physical habitat objectives into hydraulic and geomorphic criteria, which, in turn are used to select structural measures (Fischenich et al. 1994). Unfortunately, no procedure has been proposed to accomplish this.

In this technical note, a stable channel is defined as a channel that, over an engineering time scale, retains its planform, cross-sectional geometry, and grade with allowance for temporal variability about a mean that displays no trends. Existing techniques for predicting the hydraulic geometry of stable alluvial channels can be placed into two categories: 1) empirical regime equations derived from regression analyses of observed channel geometry, and 2) analytical models that attempt to model rivers on a rational basis using theoretical considerations. Knighton (1984), Chang (1988), and Mueller and Dardeau (1990), among others, present summaries of many of these techniques. The early regime equations generally relate some two-variable combination of velocity, width, depth, slope, area, hydraulic radius, perimeter, or discharge as a power function and can be generalized in the form of Equations 1 through 3, where by continuity, ack=1 and b+e+m=1:[2]

$$W = aQ^b \quad (1)$$

$$D = cQ^e \quad (2)$$

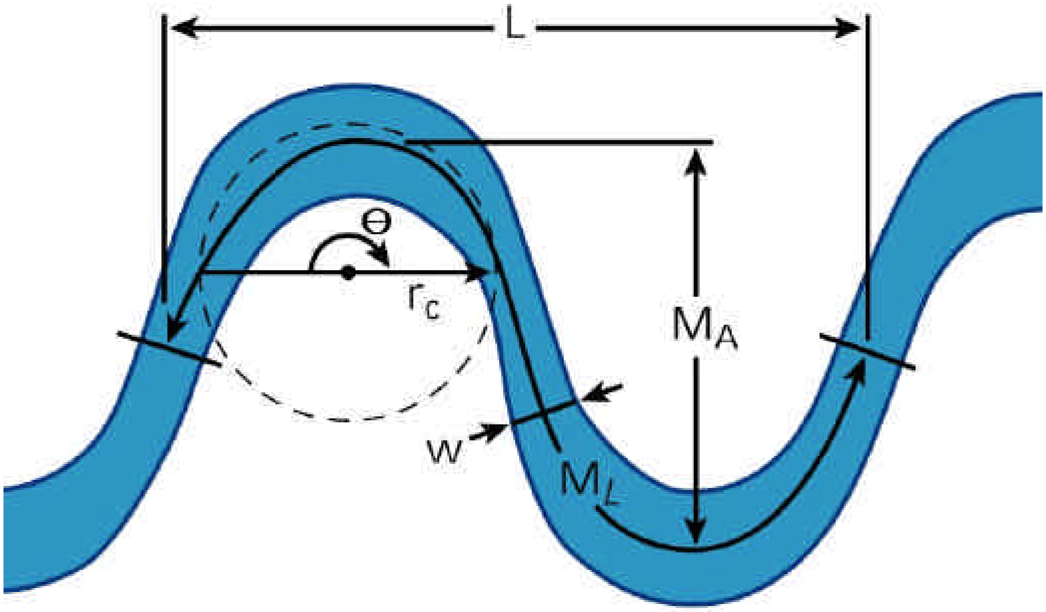
$$V = kQ^m \quad (3)$$

Analytical procedures include the method of maximum permissible velocity, the critical shear stress method, and the so-called "rational" regime equations that use tractive force theory, resistance and sediment transport laws, minimum stream power, maximum sediment transport capacity, similitude, bank stability analyses, and other concepts to overcome the fact that alluvial channels have more degrees of freedom than available relations for solution. Wargadalam (1993) showed that the existing body of literature on the subject could be reduced to no fewer than 176 equations describing depth, width, velocity, and slope in the form:

$$W, D, V, or S_0 = a_1 Q^{b_1} d_s^{\,c_1} Q_s^{\,e_1} \quad (4)$$

Despite the considerable effort expended in formulating these many approaches to stable channel geometry prediction, none are suitable for the development of stable low-flow channel designs. The reasons for this include: 1) no consideration of habitat requirements, 2) empiricism, 3) applicability only to straight channels, and 4) theoretical flaws. Perhaps the greatest limitation of many of these techniques is that they consider width, depth, and slope to be the only degrees of freedom and do not account for the full dynamic nature and multi-dimensionality of fluvial systems. A minimal description of channel morphology requires that its grade, planform, cross-sectional geometry, and some measure of channel resistance be parametrically defined. Channel grade can be described by the bed slope S_o and resistance can be described by the friction slope S_f. Channel planform requires at least two parameters, e.g., sinuosity and meander arc length. To uniquely define the cross-sectional geometry of a channel requires that at least one variable in addition to the width and depth be specified. Examples of a third variable are maximum depth, bank slope, and a channel shape factor. Figures 2 and 3 show the parameters used in describing channel geometry and planform in this paper.

[2] See page 9 for mathematical notation.



L meander wavelength
M_L meander arc length
w average width at bankfull discharge
M_A meander amplitude
r_c radius of curvature
Θ arc angle

Figure 2. Channel planform definition

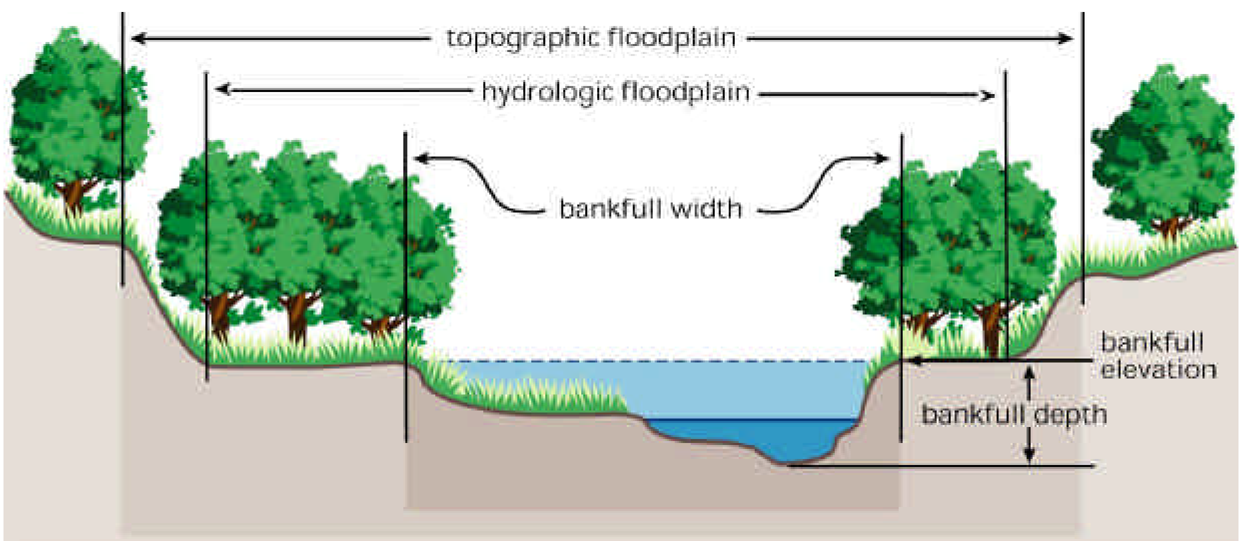


Figure 3. Channel cross section definition

PROCEDURE FORMULATION

Fundamental Considerations

Both Cartesian and curvilinear coordinate systems are used in the formulation of the procedure. The principal axis x in the Cartesian system defines the centerline of the meandering pattern in the downstream direction for planform analysis; it is aligned with the stream and is horizontal for cross section and grade analyses. The y and z axes alignments are with the vertical and horizontal, both normal to the flow. In the curvilinear system, the sinuous axis s follows the centerline of the stream, and the transversal direction remains orthogonal to the principal axis in the horizontal.

Analytical determination of the hydraulic geometry for alluvial channels can be accomplished only if applicable physical and empirical relations are sufficient to describe the unknowns or degrees of freedom. Two characteristics of low-flow channels help to satisfy this requirement. First, habitat analyses, based on biological criteria, are used to establish a minimum flow depth and an optimum velocity for the channel. Second, instream and streambank structures are typically used to stabilize the channel, provide cover and substrate, and generate diversity in velocity. Given these constraints, physical reasoning, geometric analyses, and a few semiempirical relations, a solution is possible.

A fundamental assumption in the application of this procedure is that sand bed channels tend toward a meandering planform that can be described by a sine-generated curve. Langbein and Leopold (1966) used the theory of minimum variance to show that the most probable path of a meandering stream was a sine curve. Julien (1985) showed that the fundamental shape of meandering planforms could be evaluated based on the separation of the boundary layer near the inner bank and the rate of energy dissipation. Julien (1985) demonstrated that among all possible geometries, with the exception of a straight channel, boundary separation and the rate of energy dissipation are minimized by a simple sine-generated function. Approaches based upon the Kinoshita equation, Von Schelling's curve, and Fargue's spiral can also be reduced to a form of sine-generated curve. The sine-generated function has thus been shown to fit the shape of meanders on stable rivers quite well and is the most convenient expression to use. The corresponding meandering pattern, with reference to Figure 2, can be written as:

$$\frac{dq}{dx} = -a_1 \sin \frac{2ps}{M} \qquad (5)$$

A second fundamental assumption is that the flow is approximately uniform in the streamwise direction. This assumption allows the bed, water, and friction slopes to be equated and permits the use of a uniform rating equation. The final assumption relates to sediment continuity, which must be preserved to meet the stable channel definition. The proper approach to ensure that continuity is met is to perform both longitudinal and transversal sediment transport analyses. A simplified approach is used, wherein continuity is approximated by setting the bed shear stress at the critical value for the mean bed sediment size.

Procedure

Because low-flow channels are developed for environmental purposes, the first step is to conduct hydrologic analyses to establish the target or design discharge. Instream Flow Incremental Methodology (IFIM) analyses, habitat suitability curves, or other biological criteria are then used to establish target values of velocity and depth. Realizing optimum values for both the depth and velocity objectives is unlikely; therefore, one must be established as a critical parameter. The most common case, in which a critical minimum depth is established and an optimum velocity target identified, is used here. Simple modifications to this procedure will accommodate other cases, such as a maximum velocity and an optimum depth.

Grade: The criterion of beginning of motion establishes a threshold corresponding to a condition of maximum allowable shear. The ratio of forces on an individual sediment grain on a sloping bed is evaluated to define the dimensionless shear stress called the Shields number:

$$\tau_* = \frac{\gamma R_h S_f}{(\gamma_s - \gamma) d_s} \qquad (6)$$

The critical value of the Shields number τ_{*c} corresponding to the beginning of motion, was determined by Shields (1936). For particle Reynolds numbers greater than 200, $\tau_{*c} \cong 0.05$. The widely accepted Shields diagram is used as a basis for many stable channel design techniques despite complexities encountered in its application to irregular channel geometries. Given the depth constraint and sediment size measurements, the maximum allowable friction slope for longitudinal stability can be computed from Equation 6 by setting the hydraulic radius R_h equal to the minimum depth and setting $\tau_{*c} = 0.05$. For sands and gravels of specific gravity G = 2.65, this relation reduces to:

$$S_f = 0.0825 \frac{d_{50}}{D} \qquad (7)$$

For uniform flow, channel grade can be equated to the friction slope, and either can be related to the sinuosity of the low-flow channel and measurement of the bed slope of the parent channel S_c:

$$S_o = S_f = \frac{S_c \lambda}{M} \qquad (8)$$

While this must be the reach-wise average bed slope of the low-flow channel, variation about this average to accommodate pool-riffle sequences is possible if the resultant reaches have the requisite transport capacities to ensure no aggradation or deposition. This first approximation of the channel grade ignores transversal stability, which can be incorporated into the analysis as discussed later.

Planform: With the allowable friction slope computed by Equation 7 and a measured thalweg slope of the parent channel, Equation 8 is used to establish the ratio of the meander wavelength to the arc length. Again, assuming a sine-generated curve for the planform shape and a constant velocity along the meander length, Equation 5 can be integrated for θ:

$$\theta = \frac{M\alpha_2}{2\pi V} \cos \frac{2\pi s}{M} + c_2 \qquad (9)$$

in which the maximum angle of the streamline with the downstream valley θ_m corresponds to:

$$\theta_m = \frac{M\alpha_2}{2\pi V} \qquad (10)$$

The meander wavelength is computed from the following relation:

$$\lambda = \int_0^M \cos\theta \, ds \qquad (11)$$

Defining a nondimensional curvilinear distance, s' = s/M, and rearranging with Equations 9 and 10 gives:

$$\frac{\lambda}{M} = \int_0^1 \cos\left[\theta_m \cos(2\pi s')\right] ds' \qquad (12)$$

The sinuosity is defined as the ratio M/λ and increases gradually with θ_m. Equation 12 has been integrated numerically and the results are shown in Figure 4. Figure 4 (or Equation 12) can be used to determine the maximum angle of the streamline θ_m. For a given friction slope and the assumption of a sine-generated curve, the shape, sinuosity, and maximum angle of the streamline are defined. The scale must still be determined even though the shape of the planform is known.

The radius of curvature varies along the bend as a cosecant function, and the minimum radius of curvature r_m is reached when the cosecant function equals unity. The ratio of the wavelength to the minimum radius of curvature λ/r_{cm} is

$$\frac{\lambda}{r_m} = \frac{2\pi\theta_m \lambda}{M} \qquad (13)$$

The meander amplitude A_m as defined in Figure 2 is evaluated analytically by the following integral:

$$A_m = 2\int_0^{M/4} \sin\theta \, ds \qquad (14)$$

The ratio of wavelength λ to the meander amplitude A_m is

$$\frac{\lambda}{A_m} = \frac{\int_0^1 \cos\left[\theta_m \cos(2\pi s')\right] ds'}{2\int_0^{\frac{1}{4}} \sin\left[\theta_m \cos(2\pi s')\right] ds'} \qquad (15)$$

Equations 13 and 15 have been integrated numerically and are also shown in Figure 4. The ratio λ/A_m is a function of θ_m that increases rapidly when θ_m exceeds 90° and reaches a value of 3.25 at the meander cutoff ($\theta_m \cong 125°$). The relations expressed in Equations 13 and 15 further define the planform shape, but an additional relation is needed for the size. One relation can be formulated on the basis of a limiting radius of curvature to ensure cross-sectional stability. This procedure is tedious and requires an analysis of the transversal shear stress distribution and sediment transport along the meander path. In the case of low-flow channel design, a simpler relation is available in that the meander amplitude is constrained by the width of the parent channel. The latter approach has been adopted.

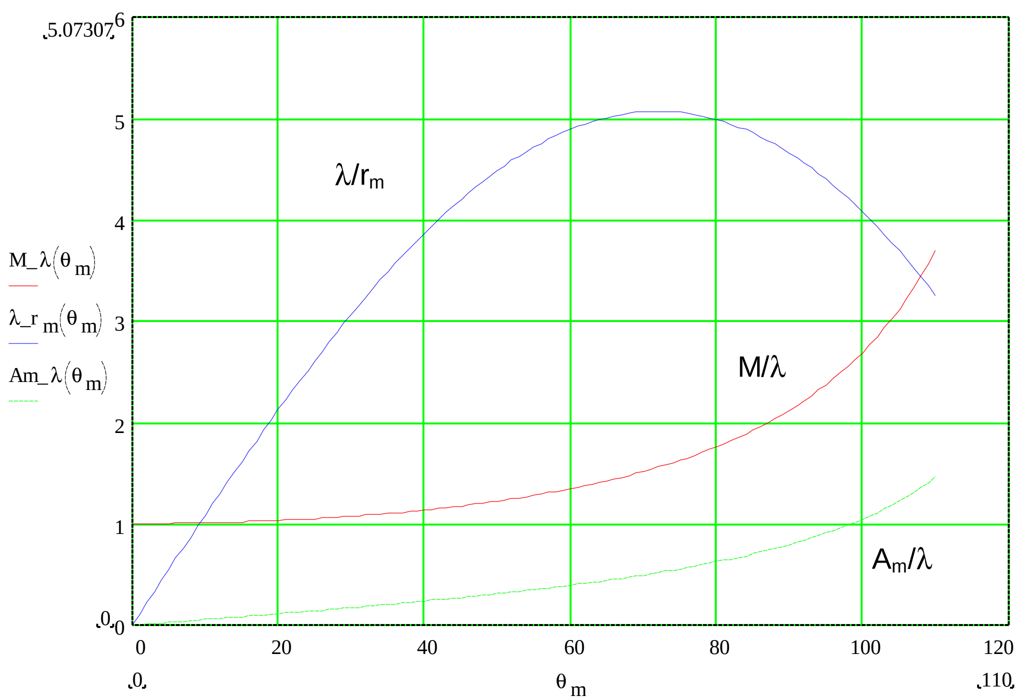


Figure 4. Planform relations

Low-flow channels are typically constructed by placing longitudinal bank protection, flow deflectors, and sills within a parent channel. The width of the parent channel at the low-flow channel elevation defines a maximum meander amplitude with no erosion of the parent banks. This is only an upper limit, and any $0 < A_m \le W_c$ will meet the shape requirements. From a practical standpoint, however, constructability and habitat benefits are optimized with the larger amplitudes. The amplitude should be set at some fraction (perhaps 90 percent) of the parent channel width, minus the encroachment of longitudinal revetment structures. With this value of A_m, either Figure 4 or Equations 12 and 15 can be used to determine the meander arc length and wavelength. The channel planform can then be laid out, and structures can be selected and located in the normal fashion.

Cross Section: Although habitat criteria were used to establish a target velocity, a rating equation is used to determine the mean velocity for the defined channel. The Manning-Strickler Equation can be used to find mean velocity V:

$$V = \frac{21.1}{d_{50}^{1/6}} D^{2/3} S_f^{1/2} \qquad (16)$$

This mean velocity must be evaluated on the basis of habitat considerations. If it is unacceptable, the depth must be adjusted, and the entire procedure must be iterated until an acceptable value of velocity is obtained. When the velocity is within acceptable limits, the principle of continuity is applied to determine the cross-sectional area:

$$A = \frac{Q}{V} \qquad (17)$$

An infinite number of cross-sectional shapes can be developed within the area and depth constraints given. However, naturally stable sand bed channels tend to have certain shapes with respect to their position, commonly trapezoidal in the crossings and a skewed parabola in the bendways. Investigators have described these shapes in terms of transversal sediment transport, force analyses, and critical transversal shear stress distribution. From a practical standpoint these complex cross sections would be difficult to construct, and the width varies little from that of a trapezoidal section. As a first approximation, a trapezoidal section with three-to-one side slopes should be used to establish the channel bottom width:

$$W = \frac{A}{D} - 3D \qquad (18)$$

DESIGN REFINEMENT AND IMPLEMENTATION

The success of this technique on sand-bed channels is virtually nonexistent due to the high transport rates of sediment under nearly all flow regimes. Success in gravel-bed streams is only slightly higher than for sand-bed streams (Fischenich 1993). Therefore, accomplishment of project objectives can be significantly improved by using structural measures such as bank protection, flow deflectors, and sills to stabilize the planform, cross-sectional geometry, and bed profile of the channel. In addition to the usual design requirements for these structures, the designer must select an appropriate structural layout with the objective of causing the stream to adopt a form that is consistent with the project objectives. Projects are too often formulated with little or no thought given to the placement of structures; as a consequence, both structural and channel stability are compromised. With no assurance of the future form of the channel, projected benefits cannot be assured.

APPLICABILITY AND LIMITATIONS

A procedure for the first-order approximation of a stable low-flow channel form has been developed based upon physical reasoning, empirical evidence, and constraints common to low-flow channel projects. More sophisticated analyses would be warranted to design the channel as nearly like its stable form as possible. However, this procedure yields a reasonable estimate of the planform and grade of the channel and maximizes probability that natural transport processes will quickly re-form the cross section without impacts to the channel stability.

Many of the assumptions used in the formulation of this procedure are not always valid. For example, the Manning-Strickler Equation is assumed to apply, which further implies that the sediment is in the sand size range and that the flow is approximately uniform. Only the longitudinal shear stress is considered in this simplified analysis. A detailed analysis should also consider the transversal stress distribution, which usually results in a decrease in the allowable friction slope. Finally, section stability under a range of discharges has not been established. Such a determination would require that friction slope decrease with increasing depth and that transport capacity through the section match the inflowing load.

Despite these limitations, this method as presented yields a reasonable first-order approximation of the stable channel form. This "stable" channel configuration can be further evaluated using more sophisticated techniques. The proposed procedure yields a close approximation of natural occurrences and thus allows the stream to make minor adjustments that conform to its newly introduced geometry.

POINTS OF CONTACT

This technical note was written by Dr. Craig Fischenich, Environmental Laboratory (EL), U.S. Army Engineer Research and Development Center (ERDC). For additional information, contact Dr. Fischenich (601-634-3449, *craig.fischenich@erdc.usace.army.mil*) or the manager of the Ecosystem Management and Restoration Research Program, Mr. Glenn G. Rhett (601-634-3717, glenn.g.rhett@erdc.usace.army.mil).
This technical note should be cited as follows:

Fischenich, C. (2002). "Design of low-flow channels," *EMRRP Technical Notes Collection* (TN EMRRP-SR-19), U.S. Army Engineer Research and Development Center, Vicksburg, MS. *www.wes.army.mil/el/emrrp*

ACKNOWLEDGEMENTS

Research presented in this technical note was developed under the U.S. Army Corps of Engineers Ecosystem Management and Restoration Research Program. Technical reviews were provided by Dr. Ronald R. Copeland, Coastal and Hydraulics Laboratory; and Mr. Jerry L. Miller, Mr. Jock Conyngham, and Dr. Wilma A. Mitchell, EL, ERDC.

REFERENCES

Chang, H. H. (1988). *Fluvial processes in river engineering*. John Wiley & Sons, New York.

Fischenich, J. C., Abt, S. R., Watson, C. C., Peters, M., and Walters, R. W. (1994). "Environmental engineering of low-flow channels," Technical Report EL-94-12, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Julien, P. Y. (1985). "Planform geometry of meandering alluvial channels," Civil Engineering Research Report, CER84-85PYJ5, Colorado State University, Fort Collins.

Knighton, D. (1984). *Fluvial forms and processes.* Edward Arnold, London.

Langbein, W. B., and Leopold, L. B. (1966). "River meanders - theory of minimum variance," USGS Professional Paper 422-H, Washington, DC.

Mueller, D. S., and Dardeau, E. A., Jr. (1990). "Impact of changes in suspended-sediment loads on the regime of alluvial rivers," Potomology Program Report 6, U.S. Army Engineer Division, Lower Mississippi Valley, Vicksburg, MS.

Shields, A. (1936). "Anwendung der aehnlichkeitsmechanik und der turbulenz forschung auf die geschiebebewegung," Mitteilungen, Preussische Versuchanstalt fur Wasserbau und Schiffbau, Berlin.

Wargadalam, J. (1993). "Hydraulic geometry equations of alluvial channels," Ph.D. diss., Colorado State University, Fort Collins.

NOTATION

A	cross-sectional area of the channel
A_m	meander amplitude
$a, a_1, \ldots$	empirical coefficients
$b, b_1, \ldots$	empirical coefficients
$c, c_1, \ldots$	empirical coefficients
d_s	sediment size
D	average flow depth
D_c	average depth in parent channel
d_{50}	representative bed sediment size
e, k, m	empirical coefficients
Q	total discharge
Q_s	sediment load
r_m	minimum radius of curvature
R_h	hydraulic radius
M	wavelength path distance
s	curvilinear longitudinal distance
s'	dimensionless curvilinear distance
S_f	friction slope
S_o	bed slope
S_c	bed slope of parent channel
V	cross-sectional average downstream velocity
W	channel width
W_c	parent channel width
w	curvilinear transversal coordinate
x	Cartesian longitudinal coordinate
y	vertical coordinate
z	Cartesian transversal coordinate
γ	unit weight of water
γ_s	unit weight of sediment
λ	meander wavelength
θ	angle of streamline with x
θ_m	maximum angle of streamline with x
τ_*	dimensionless Shields number
τ_{*c}	critical Shields number